ECONOMIC BOTANY

DEVOTED TO APPLIED BOTANY AND PLANT UTILIZATION

VOLUME 14

NUMBER 1

JANUARY — MARCH, 1960

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Founded by Edmund H. Fulling

VOL. 14 JANUARY-MARCH, 1960 No. 1

Title page of Volume 13 bound in this issue.

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Published quarterly by The New York Botanical Garden for The Society for Economic Botany. Printer: Monumental Printing Company, 32nd Street and Elm Avenue, Baltimore 11, Maryland.

Second class mail privileges authorized at Baltimore, Maryland.

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Memorial Center

Purdue University

Lafayette, Indiana

May 21 and 22, 1960

PROGRAM

Saturday, May 21

9:00-10:30 A.M.	Registration
10:30-12:30 P.M.	Session for contributed papers
2:00- 5:00 P.M.	Session for contributed papers
6:30 P.M.	Dinner and presidential address. Business meeting follows.

Sunday, May 22

9:00-12:30 P.M.	Symposium: Integrated research in economic plants. I. Drugs and essential oils. Topics and speakers to be announced.
1:00- 2:30 P.M.	Luncheon and speaker. Close of meeting.

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The Production, History, Uses and Relationships of Cotton (*Gossypium* spp.) In Ethiopia[1]

The development of a cotton textile industry in Ethiopia based upon increased national production of raw cotton is gradually taking place. The study of the cottons of Ethiopia is a necessary step in the breeding of suitable varieties. Cotton has been grown and used in Ethiopia since ancient times, and hand spinning and weaving is still a well established and widespread craft. One of the Old World species of cotton used may be indigenous. Ethiopia is one of the centers of variability and domestication of several cultivated plants, and it is probable that cotton was also domesticated in this region. This work reviews the available information and indicates the possible place of Ethiopia in the origin and development of the cultivated cottons.

G. EDWARD NICHOLSON[2]

Introduction

Ethiopia is one of the areas of Africa where an advanced civilization and culture has existed from very early times. The Kingdom of Axum was established in what is now northern Ethiopia in about the third century B.C., and was therefore contemporary for a time with the Kingdom of Meroe in the Sudan. There is, in addition, much evidence of earlier contacts with Egypt and the civilizations to the East, specially Arabia and India (35, 110). The country became officially Christian in the fourth century A.D., a fact which later produced the legend of Prester John, and thereby in part led to the Portuguese expeditions of the fifteenth and sixteenth centuries.

Ethiopia consists mainly of a mountainous rugged central plateau dissected into different sections by deep canyons, especially those of the Blue Nile and Rift Valleys. The highlands are surrounded in almost every direction by deserts or semideserts, and they have always been difficult of access. This circumstance made in the past for long periods of isolation from contact with surrounding peoples. The central plateau (generally at about 8,000 ft. altitude) is cool, well watered and fertile. It is occupied by Christian Amhara people particularly towards the north. The rest of the country is inhabited by a large number of different tribes and linguistic groups. The terrain and climate vary considerably, roughly in accordance with altitude, though there are also differences, especially in rainfall pattern, between the northern and southern highlands. A wide variety of crops are grown and there are vast areas of natural grasslands where very large numbers of cattle are kept. Some of the most important crops are wheat, barley, sorghum, teff (*Eragrostis teff* (Zucc.) Trotter), coffee, several oil crops, and cotton.

The Ethiopian region is considered to be one of the important world centers of domestication of plants (5, 121, 143, 144) and the cultivated plants of the country are, therefore, of considerable interest. Cotton has been one of the more valuable and extensively grown crops of Ethiopia for a very long time. An old and well established "cottage" industry in hand spinning and weaving cotton also exists. (Fig. 1.) However, in the absence of adequate information it has been impossible until recently to take Ethiopia fully into account in the study of the cultivated cot-

[1]The present day Empire of Ethiopia includes the federated territory of Eritrea and part of the territories collectively known as Somaliland or Somalia.

[2]Guggenheim Foundation Reseach Fellow, 1958-1959.

Fig. 1. Seed cotton is sold in all the Ethiopan country markets. The cotton is classified into different qualities, each of which is sold at a different price. Spinners examine these qualities very carefully before buying small amounts of each.

tons of Africa. Similarly, the study of other cultivated plants, and indeed of the flora of Ethiopia, is a relatively neglected subject (54). The opening of the country and the existence of adequate travel facilities into the interior are of recent date, and extensive modern work on Ethiopian crop plants began only in the late twenties and thirties of this century. There is no published flora as yet, or a complete account of Ethiopian agriculture, though all these are in preparation[1].

[1]Chiarugi and others in Webbia, 1953-1957; Cufodantis in Bull. Jard. Bot. Etat., Brussels, 1953-1958; and Food and Agriculture Organization (United Nations), Agriculture in Ethiopia (in manuscript).

The cultivated species of cotton at present found in Ethiopia, as far as it is now known on the basis of recent collections and field studies made by Nicholson[2] (107), are the following: (classification and nomenclature of Hutchinson, Silow and Stephen, 1947) *Gossypium barbadense* L., *G. hirsutum* L., *G. hirsutum* var. *punctatum*, and *G. herbaceum* var. *acerifolium*. There are also many intraspecific hybrids in *G. hirsutum*. With some exceptions, entirely in the case of recent introductions of *G. hirsutum* and *G. barbadense*, all these cottons are perennials in

[2]Collections deposited in Cotton Div., Min. of Agr., Addis Ababa, Ethiopia.

Ethiopia. The perennials are grown for varying periods of three to five or more years. Ratooning is not practiced. Neither *G. arboreum* nor annual *G. herbaceum* occur in recent collections. In these collections the most widespread species by far is undoubtedly *G. hirsutum* var. *punctatum,* while *G. herbaceum* var. *acerifolium* now occurs only in areas of South and Southwestern Ethiopia, and on the Uebe Shebelli river valley in Ethiopian Somaliland.

The distribution of Ethiopian cottons, the cotton growing areas of the country, and cultivation methods have been discussed elsewhere in some detail[1] (104, 106). It is clear that perennial introduced New World cottons (*G. barbadense* and *G. hirsutum* var. *punctatum*) are spreading rapidly in peasant cultivation. The commercial cultivation of annual cottons for use by the textile mills is only just beginning, and much experimental work remains to be done. On the whole, the most successful results from recent introductions have been obtained with Upland varieties developed in Uganda and the Sudan. As is well known, these varieties are developed from old African stocks resistant to jassids (*Empoasca* spp.). Jassids, other insect pests, and some diseases such as *Fusarium* wilt, are present in several areas of Ethiopia, and it is necessary in such areas to grow resistant varieties. In addition, the variability of climate and altitude also require a wide range of adaptability in the varieties grown. In the breeding of suitable cottons to meet these and other conditions, the perennial species and types of Ethiopia are likely to be a good source of desirable characters. Hence, the collection and study of these cottons is an important stage of any future breeding program. Much more information is needed, but the basis is being laid for long term research into these problems.

[1]The library of the Italian Agricultural Institute, Florence, contains useful unpublished manuscripts by Italian authors, some of which are listed in Nicholson, 1956. (105) See also Joyce, Major F. de V., "Notes on Agriculture in Ethiopia," East African Agricultural Journal, 1943.

Production and Consumption

All of the raw cotton produced in Ethiopia is consumed by the cottage industry. This cotton is produced in very small quantities by peasant farmers all over the country. There are some areas, mainly in Eritrea, where cotton is produced on a larger scale and is mechanically ginned, but these are still exceptional. Some of this "plantation grown" cotton, as well as all of the imported raw cotton, is consumed by the textile mills. These mills produce yarn and cloth, but much of the yarn is used by the hand weaving industry. However, the capacity of the cottage industry and the textile mills taken together is not sufficient to meet the needs of the country, so that the most important Ethiopian import (about one third of the total value of imports) is manufactured cotton.

The estimated annual consumption of cotton textiles in Ethiopia is about 68 million square meters. If the population (in the absence of a census) is taken to be 16 to 18 million, the per capita consumption is about 4 square meters (105). This is well above the average for Central Africa, which is to be expected in a country with an ancient tradition of growing and using cotton. Furthermore, consumption is increasing.

The tendency since the end of the second world war has been to increase the capacity of the textile mills and to reduce textile imports. In this way the nucleus of a future textile industry has now been established. But, since the mills consume imported raw cotton the present aim is to increase raw cotton production in Ethiopia to meet, in the first place, the internal needs of the existing Ethiopian mills. Both private industry and the government are co-operating in this work. A relatively

Fig. 2. Cotton trials with several introduced Upland varieties grown at about 4,000 feet on deep, heavy, black soils.

large national market for cotton textiles greatly favors the expansion of production of raw cotton and of textile manufactures. The extent of the market indicates that a large concentration of productivity is already directed to this sector of the economy, a factor which offers adequate inducement for future investments.

There are several areas in Ethiopia where cotton might be grown on a commercial scale under either rainfall and/or irrigation. Estimates of the total potential area suitable for cotton growing without a reduction in the production of other crops vary considerably. An estimate made in 1938 during the Italian occupation stated that "Abyssinia can grow good American cotton to the extent of about 900,000 quintals yearly" (104). In terms of area, the more conservative estimates put the potential at about 500,000 hectares. But even a much smaller area than this would contribute substantially to meeting the needs of an expanded Ethiopian textile industry.[1]

The most suitable types of cotton for consumption by the textile mills are short staple (about one inch) American Upland cottons (*G. hirsutum*) of both North American and African origin. (Fig. 2) Coarse yarns and rough cloth are the principal products of these mills. Upland cottons are also the most suitable for Ethiopian conditions, especially in highland areas (4,000 to 5,000 ft. high), where cotton is grown under rainfall, or under a combination of rainfall and supplementary irrigation. In the irrigated lowland

[1]The Development of the Awash Corridor Region. Report by the Planning Consultants to the Imperial Ethiopian Government, 1959. See in particular the map on page 72.

areas long staple Egyptian types (*G. barbadense*), of both North American and African origin might be grown instead, as is already the case in parts of Eritrea. These longer and finer cottons are at present exported from Eritrea to Europe. This trend might well continue into the future. On the other hand, changes in consumption habits are already in progress. At the present time the greatest consumption is of "abujedid" (grey sheetings), mostly from India. But more of the better quality textiles are being used, including relatively large quantities of khaki and drills. There is every possibility that longer staple American Upland cotton (1 inch to $1\frac{3}{32}$ inches) can be used in the future by some of the textile mills. The following varieties, grown on extensive commercial trials at about 4,500 ft., under a combination of rainfall and irrigation, have given promising results: 'Deltapine', 'Empire', 'Wilds', 'Acala' and 'Stoneville' (106).

History

Ancient and Medieval Times. The well known inscription of the Axumite King Aizana, dated approximately 350 A. D. in which the reference is unquestionably to raw cotton (39, 80) and the discovery of fragments of cotton textiles of about the same period at Meroe and Karanog (58, 95), are the earliest factual indications of cotton cultivation in the Sudan and perhaps in Ethiopia; indeed in the African continent. Although the Karanog fabrics are of great interest the possibility cannot, however, be discounted that "the Red Sea trade, much developed in Roman times, might have introduced cotton from India to the Meroites" (58). Commenting on the Axumite inscription, Crowfoot (39) wrote in 1911: "—the fact of greatest economic importance preserved in this inscription is the introduction of cotton, the modern Abyssinian word for which is used in the Ethiopian version of this record. From the Periplus we know that cotton goods were exported from India to Adulis in the first century of our era." Crowfoot suggested that the links between Meroe (about 650 B. C. to 350 A. D.) and Axum were so close that Meroe might prove to have been "a single system with the culture of Axum, with which it certainly had commercial dealings." The use of the Amharic word for cotton (tut) indicates that Axum had long known of the existence of the raw material as well as of cotton textiles. In this connection, it is interesting that the inscription says that "my people took from them" iron and bronze, but they "destroyed the idols contained in the houses and also their stores of corn and cotton," and that the inscription refers to people of the lower Takazze. According to Crowfoot, the wealth of Meroe may have resulted from the extensive cultivation of cotton, and it has been suggested that the species grown might have been *G. arboreum* (71, 75). If this was indeed the case in the early centuries of our era at a time when Axum was already importing the finest textiles of India and had close commercial links with Meroe, it is not improbable that cotton was also grown in Ethiopia and Nubia at that time[1]. It may well be, also, that the Meroitic cotton was not *G. arboreum* but perennial *G. herbaceum* (116).

The evidence is not conclusive on this point. The report of the examination of the Karanog material stated that, "these tests show that it is at any rate not impossible that these Nubian cloths may have been made from a native cotton

[1]Crawford (37), concluded that cotton "was known and probably grown, in Christian Nubia, and formed one of the products exchanged as part of the baqt." Goosens (56) has suggested that the cotton used in the manufacture of corselets for the Egyptian King Amasis (568-525 B.C.), as mentioned by Herodotus, came from Nubia and not from India (65, 83). See also Moldenke (1954), "The Economic Plants of the Bible" (Econ. Bot. vol. 8, no. 2, pp. 152-163).

Fig. 3. Perennial tree cotton grown in the Takazze River Valley by Agow people. Photo by Frederick J. Simoons.

similar to *Gossypium arboreum Soudanensis,* but it would obviously not be safe to conclude, in the absence of other evidence that they have actually been so made" (58). The fact clearly stated in the inscription of King Aizana that his expedition advanced to the Takazze, and that it was there that the stores of cotton were found indicates both the probable area where this cotton must have been grown, and the close link with Ethiopia. It is well established that the Agao of northern Ethiopia once occupied a much greater territory than at present and it is likely that *G. herbaceum* var. *acerifolium* was cultivated much more extensively in Ethiopia in the past, and may have spread along the Takazze (Fig. 3) and other routes to the territory of what is now the Sudan. The relatively large imports of Indian cotton textiles to Adulis attest to a demand based upon a long tradition of using good quality cotton cloth. But production based upon a perennial cotton and without the spinning wheel (which originated in India not earlier than 500 B. C. and perhaps much later, and was not introduced to Africa), could not have met the demand.

The Periplus of the Erythraean Sea

(122) written by an unknown Greek author in 60 A. D. approximately, or 300 years before the date of the Aizana inscription, contains the first definite commercial mention of Indian cotton textiles which were conveyed from "patiola Anake and Barygaza" up the Red Sea to "Aduli", the principal Axumite port. This trade was extensive and varied even though neither Adulis nor Axum had obtained at this time the importance that they acquired in the succeeding centuries. It is mentioned for instance, that the ivory was brought to Adulis from as far as "the district called Cyeneum" which is believed to be the modern Sennar in the Sudan, and that among the imports there were not only a variety of cotton textiles from India but also various metals (brass, copper, iron), glass, wine (from Syria), a little olive oil (from Italy), and some manufactured products such as axes and swords. Other products from India were wheat, rice and sugar.

The classical authors of this period from Herodotus (450 B. C.) to Virgil have been thoroughly studied for references to cotton, specially to cotton in Egypt, but unfortunately without very positive results regarding Africa (43, 146). Neither cotton nor cotton textiles appear to have been known in Egypt before the Arab conquest in 640 A. D. at the earliest, and possibly not until after the beginning of the 13th century (57, 114, 149). Perhaps the most accurate as well as the most interesting of the classical references is that in Theophrastus (350 B. C.) who seems to describe two different types of cotton, one in India and one on the island of Tylos in the Persian Gulf. Both Watt (149) and Yates (146) suggested that the reference is to *G. arboreum* and to *G. herbaceum* respectively (116).

The later development, trade and prosperity of Axum is attested for in some detail by Cosmos Indicoplenstes (36), a shipmaster who traded in the Red Sea, including Adulis, in the sixth century A. D. By this time Christianity had been adopted by the Axumite Kingdom (about 350 A. D.), and there had been a marked territorial expansion mainly to the west and north and into Arabia. In 524 A. D. an Axumite army crossed to Arabia and commercial contacts were established as far as Persia, Ceylon and China. But the Persian occupation of Arabia, Yemen and some ports on the African coast in 602 A. D. reversed this expansion and marked the beginning of the decline of Axum. Although cotton is not mentioned in the account of Cosmos Indicoplenstes he makes several references to the variety of exports from Ethiopia, and refers to "Adule, which forms the port of the Axomites and is much frequented by traders who come from Alexandria and the Elanitic Gulf." By the 13th century cotton trade had become general in much of Africa and Asia, and with increasing contacts with the interior of Africa, cotton growing is mentioned oftener. In 1172-73, Turan Shah, brother of Saladin, captured a large quantity of cotton in Lower Nubia, and Marco Polo in 1290 mentions that both Socotra and "Albash (Abyssinia) possess much cotton and manufacture fine buckrams" (149).

It is thought that the Persians who settled on the East African coast in 975 A. D. to form the Zenj Empire, centered at Kilwa, brought with them "the knowledge of how to build in stone, carve wood, and weave cotton" (94). They controlled the coast as far north as Mogadishu, and the cotton of Socotra may have been introduced by them. The Persian settlements gradually became more and more Arab so that Duarte Barbosa by 1516 (12, 147) could write of the "Moors" as having "now recently begun to produce much fine cotton" around Sofola. He goes on to say that the people of the interior in the Kingdom of Benamatapa "go bare, but covered from the waist downward with coloured stuffs, or skins of wild animals," and

"their women go naked as long as they are girls, only covering their middles with cotton cloths."

Our knowledge of the peoples of the interior of Africa at this time is still very incomplete, but Wainwright (148) has put forward a convincing case to show that the non-Bantu influence in Zimbabwe-Monomotapa (82) did not come direct from pre-Islamic south-western Arabia, but came from southern Ethiopia via Gallaland just before the 9th Century A. D. This influence may have originated from the present day Hamitic and Nilo—Hamitic groups in south and west Ethiopia, especially the Sidamo—Wallamo, Konso and Kaffa (78). The possibility exists, therefore, that the cotton garments worn by the people of the interior as described by Duarte Barbosa were made from cotton introduced from southern Ethiopia several centuries before his visit (73).

The Fifteenth and Sixteenth Centuries. The theme of "much cotton" and "fine" textiles from Ethiopia runs like a continuous thread through the accounts of European travellers from the late 14th to the 19th century. The recent publication in 1958 of Crawford's "Ethiopian Itineraries" circa 1400-1524 (the Zorsi and other itineraries) (38), has made available in a corrected and easily accessible edition, very valuable information on the historical geography of Ethiopia during the 15th century before the Granh and Galla invasions of the following century. The Itineraries contain interesting references to the agriculture of the country as well as some specific references to cotton growing. Thus in 1522 Zorsi obtained information from Brother Raphael of the Order of St. Francis about the agriculture of the Axum region, which contains the following observations: "There is much silk and cotton grown there and they make clothes (panni) of silk wool and cotton, very fair and abundant, which they wear."

The information supplied by Brother Thomas about the country as a whole included the following description: "The women are fair and many without a dowry; instead those men who would marry give money to the fathers that they may have them. They stay indoors to sew and do their embroidery, and to spin; besides silk and cotton that they have for spinning, there is a great tree called (   )[1] which makes balls as big as pomegranates, full of a certain silk as fine as silk and more lustrous and fair, whereof they make embroideries for the Presta and also for the great lords." This reference to "a great tree" is repeated by Brother Thomas in his description of the fair at Durbit where they bring "cloth of silk and of another sort finer and more lustrous and fairer than silk, and this is a certain tree called Arid." It is clear that Arid could not be cotton both from the description and from the specific statement in the first reference quoted above

It is not improbable that this tree was kapok (*Ceiba pentandra*, L), which grows in Ethiopia. The description applies well, specially the reference to its size, and to the silkiness, fineness and elasticity of the floss. However, the fibers of kapok are too short to be used for spinning, and the reference to its use for "embroidery" may therefore indicate some other fiber. On the other hand, it is well known that some of the Spaniards and Portuguese of the 15th and 16th centuries erroneously believed kapok capable of being spun. There is for example, the well known letter of Dr. Chanca (92), physician to the fleet of Christopher Columbus, describing a tree on the island of Expañola (Santo Domingo) that is undoubtedly kapok: that "besides silk and cotton" they have for spinning this other "great tree."

"We have met with trees bearing wool, of

[1]Omitted, as in the original.

a sufficiently fine quality (according to the opinion of those who are acquainted with the art) to be woven into good cloth; there are so many of these trees that we might load the caravels with wool, although it is troublesome to collect, for the trees are very thorny, but some means may be easily found of overcoming this difficulty." That Dr. Chanca was able to distinguish kapok from cotton is shown by his remark that there are "also cotton trees as large as peach trees, which produce cotton in the greatest abundance." A similar error may have been made by Brother Thomas if his description of "arid" does indeed apply to kapok.

The earliest work extant to Ethiopia written by a European traveller is the famous Narrative of the Portuguese Embassy to Abyssinia during the years 1520-1527 written by Father Francisco Alvarez (3) and published in 1540. He often mentions the agriculture and plants of Ethiopia, where "there is much cotton, and stuff made of it; there is much coloured cloth and there is a very cold country where they wear serge", and "they have sugar likewise (not knowing how to refine it), and honey, and cotton-wooll" (from Pory). Of the friars and nuns he wrote: "Some wear yellow habits of coarse cotton stuff, others habits of tanned goat skins like wide breeches, also yellow. The nuns also wear the same habits." The 17th century travellers also report the cultivation and use of cotton, specially the Jesuit Father Manoel de Almeida (15) who visited some of the more remote areas. Almeida's History was written between 1628 and 1646, and contains several references to cotton (pp. 25-26, 42, 27, 57, 60, 86) of which the following are of special interest: "These valleys between Gojam, Begameder, and Olecâ are inhabited and produce much cotton, but it is a country of many diseases. In this region the mountain ranges of Gojam are so precipitous as to be frightening, specially those that run from before Adoscâ as far as Nebessê." In another place he also adds that "common people make their breeches of thick cloth of native cotton."

Almeida also offers perhaps the only actual description of the Ethiopian cotton plant, which although brief and vague, at least tells us that it was not a large tree type cotton: "There is much cotton which grows in bushes like Indian cotton. They make much cloth from it, some of it very good and fine." Like other travellers of the period (24) he mentions the importance of cotton cloth as a form of tribute exacted by the rulers: "three thousand pieces of cloth are raised from the same Kingdom (Gojam), each of which is worth a pataca, and two hundred Bezetes, which are very large, closely woven cotton cloths with the hair of the cotton used as a border as in carpets; each one of them is worth about an oguea; (Footnote: Amharic bezet, 'cotton prepared by hand for carding'—Guidi—, a form of tribute recorded in Le canzoni geez—amariña in onore di Re Abissini, from several places)." Later, Almeida writes that the Emperor himself, "receives besides from every weaver weaving cotton cloth one piece of cloth from the Christians and one drime or petaca from the Moors. From this source of revenue he collects in Dambeâ and other neighboring districts many thousands of pieces of cloth every year." At least one of the important uses for this cloth must have been for tents. There was no permanent capital and the Ethiopian kings and their court were always moving from place to place. Pory gives some idea of the numbers involved: "The most populous place in all Abassia is the court of the Prete, wheresoever it resideth; and there are erected five or six thousand tents of cotton of divers colours." According to Almeida, the number of people living in these tent cities was at least 30,000, but when a whole army moved in force "the whole multitude is over a hundred or a hundred and twenty thousand."

Modern Times. The almost unfailing mention of cotton in Ethiopia by travellers continued into the late 18th and 19th centuries, but these later accounts are of special interest in that cotton cultivation is described in some of the less well known

Fig. 4. (Upper) An Ethiopian popular art illustration of the cotton "cottage craft industry." The two figures in the foreground are shown "ginning" (right) and "fluffing" (left) cotton.

Fig. 5. (Lower) Another popular illustration showing "ginning" and spinning in greater detail.

areas of Ethiopia. In addition, valuable information was gathered by anthropologists and ethnologists (25, 68, 117). The results of these explorations, confirmed by modern surveys, specially by the Italians during the 1935-1941 occupation of Ethiopia, led to the first attempts to develop cotton production in the country early in this century. But the first intensive effort to grow cotton on a large commercial scale was made by the Italians. This work was interrupted in its initial stages by World War II. The present phase in cotton development, therefore, began only in 1948 with the first request of the Ethiopian Government for technical assistance from the United Nations and other agencies for further surveys, planning, research and the training of Ethiopian personnel.

Uses

Cottage Industry. The spinning and weaving of cotton in Ethiopia is a complex home industry involving thousands of people all over the country (Figs. 4 & 5) (50, 104). A long process is involved requiring knowledge and skill, from the classification of seed cotton in the market into different spinning qualities, and the "ginning" of cotton by hand, to the spinning of yarns suitable for different materials (all done by women) (Fig. 6) and the weaving of these materials (all done by men) (Fig. 7). It is characteristic of the industry that machine ginned cotton is never used by the spinners who invariably reject it, whether imported or locally produced. The same situation was recorded by Crawfoot in 1924 in the Sudan where the hand spinner also "must have cotton on the seed. (Fig. 1) It is quite impossible to spin fine thread on a hand spindle from machine ginned cotton" (40).

The first accurate account of this craft as practiced in Gondar in northern Ethiopia appears to be that given by the French Scientific Mission to Ethiopia of

Fig. 6. Preparing yarn for weaving.

Fig. 7. Weaving a thick blanket.

1840-1843 (118). But, as already mentioned, the spinning and manufacture of cotton fabrics in Ethiopia is a recurring theme in most of the accounts by travellers from medieval times onwards. The spinner in Ethiopia, as in the Sudan, does the "ginning" or de-seeding herself either by removing the seed from the lint with the fingers or by using a smooth flat stone, or wood block, on which the seed cotton is "rolled ginned" with a thin iron rod which pushes the seeds away from the lint. The most important aim in this process is to get even fibers, lying as parallel to each other as possible, so as to increase the durability, softness and warmth of the fabrics made from such hand spun yarn.

Kinds of Dress. There are at present, unfortunately, no written records of cotton manufacture or samples of material from Ethiopia dating from very early times. However, imports of cotton fabrics from India to Adulis in the first century A. D. shows that at that time the Axumites were familiar with such fabrics. But it is very likely that most of these imports were destined for the use of the court and high officials, and not for the mass of the people. The account of Father Jerome Lobo, written in the 17th century, shows the difference in dress that existed at that time in Ethiopia between the "people of quality" and the lower orders: "The meaner sort of people here dress themselves very plain; they only wear drawers, and a thick garment of cotton that covers the rest of their bodies. The people of quality, specially those that frequent the court, run into the contrary extreme, and ruin themselves with costly habits." They also wore "all sorts of silks, and particularly the fine velvets of Turkey." Almeida mentions of both men and women that "the poorest have no pieces of cloth except dressed ox skins," and that the "ordinary people" wear "breeches of thick cloth of

native cotton." He adds that the "richest wear in preference something like Baniane cabayas" (a tunic) over which they wear "pieces of fine local cloth or bofetàs", though for some lords and richer men these are of "satin and damask." Alvarez describes the dress of the "Abima" or Abuna (the head of the Ethiopian Coptic Church, and one of the "great people of this country") as consisting in part of a "white cotton robe of fine thin stuff, and in India from whence it comes it is called cacha."

It is perhaps for this reason that the practice exists in Ethiopia, as in other regions, of unravelling imported silk fabrics to use the thread for weaving silk borders on the finer local cotton fabrics. The best quality imported cotton textiles are also similarly unravelled in some areas, though perhaps the reason in this case lies in the superior quality of the dyes used in the imported cotton. In dyeing, as stated by Bruce, "they are great novices; the plant called Suf produces the only color they have, which is yellow. In order to obtain a blue, to weave as a border to their cotton clothes, they unravel the blue threads of the Merowt, or blue cloth of Surat, and then weave them again with the thread which they have dyed with the Suf." The word Suf is Amharic for safflower or "False Saffron," (*Carthamua tinctorius* L.), a common cultivated plant of Ethiopia. A red as well as a yellow color is obtained from the flowers, but while the red is quite permanent, the yellow is water soluble. The plant is mainly grown at the present time for the oil extracted from the seeds. In ancient Egypt, safflower was grown for both purposes, and to-day it is used as a component of "Kohl", a cosmetic (eye-paint) of the Egyptians.

The colored and highly decorative border of some Ethiopian textiles is specially important for the "shamma" (or samma), the characteristic shawl or mantle worn by both men and women everywhere in the highlands of Ethiopia. This is always made of cotton and it is worn draped over the shoulders with the colored edges showing. The French Mission made the observation in a passage translated by Pankhurst (110), that "as it was desired to produce a fabric which lent itself readily to draping in graceful folds, the weavers did not use the same thickness for the warp, which runs in a longitudinal direction, as for the woof, which crosses it horizontally; they employed for the warp thread finer at least by a half than the thread of the woof."

The importance of this cottage craft, and of quality fabrics for the aristocracy, is best illustrated in the description by Johnston (*79*) of the Imperial court in the 19th century which included a large group of "two hundred young ladies," who spent most of their time spinning cotton: ". . . the more elaborately-spun cotton thread, that is used for the finer descriptions of cotton cloths, which are presented by the Negoos to his greatest favorites and governors, is all made by the members of this portion of the royal household." Furthermore, certain types of cotton weave and materials have become associated with certain high offices so that the cotton fabric awarded as a gift from the Emperor in the past has itself become the outward symbol of favor and authority. Thus the "Dirib is a specialized cloth worn only by high dignitaries on special occasions, and is an outward sign of reward for services rendered or of special appointment to high office" (104).

Other Uses

Cotton is still used to some extent in Ethiopia for purposes other than spinning and weaving. The leaves, flowers, seeds and roots are used medicinally, both internally and externally. Cotton seed oil is rarely used for cooking, but a fermented cake containing cotton seed is sometimes made in the south west. There are also some associations with magic and ritual.

Hodson (67), for instance, writing of the Wallamo, observed the custom of "tying a piece of cotton round a tree. This, it appears, is done to bring good luck—for example, by a man who wishes his wife to present him with a son." The use of cotton cloth as money appears to have been common even at the time of Bruce's visit to Ethiopia. He reports that Adowa in northern Ethiopia "is the seat of a very valuable manufacture of coarse cotton cloth, which circulates all over Abyssinia instead of silver money; each web is sixteen feet long of one and three quarter inch width, their value a pataka; that is, ten for the ounce of gold." Similarly, Sirè, to the south, "is famous for a manufacture of coarse cotton cloths, which pass for current money through all the province of Tigre" (20).

Use of Other Textile Fibers

The only plants other than cotton still used for clothing in Ethiopia, are *Ensete edule*, recently renamed *E. ventricosum* (Welw.) Cheesm. 1947 (11, 139), and some bark fibers, but none of these are as important as cotton. Flax, which is grown in Ethiopia in large quantities, specially in the higher altitudes, is used entirely for oil. The use of ensete leaves and fiber for clothing is confined to some regions in the south and west of Ethiopia, and is a practice that has almost disappeared. The plant is mainly a food plant and the fiber is mainly used for ropes and mats. Bruce (20) mentioned that the leaves were used by people near the Little Abbai river south of Lake Tana (the Zoghie Peninsula), but this custom seems to have been more characteristic of the south, specially Kaffa, rather than the north.

Montandon (100) and Cerulli mention the use of ensete leaves in Kaffa in this way. Cerulli describes the Kaffa women as wearing "un corto gonellino a striscie di foglia di ensete", and also refers to the use of fiber by the Ampillo or Mao (59) of western Ethiopia whose traditional dress "è molto simile a quello del Caffa Occidentale e dei lontani Chimira. Esso consiste in un ampio mantello di fibra intrecciata; mantello che è infilato al collo e copra in lunghezza tutta la persona." Similarly, the Magi of the south-west, like other neighboring peoples, "soglion farsi mantelli di ensete o di altra fibra e spesso questi mantelli constituiscono la loro sola veste." The Magi also make cloaks of ensete for use in rainy weather (102). Mat making from ensete is still fairly common in some areas of Ethiopia, but it was probably much more widespread in Almeida's time since he specifically refers to the practice in detail: "The leaves or leaf-stalks unravel like strikes of thick flax and from them very good and handsome mats are made."

The only people in these groups who also grow cotton and manufacture cotton textiles are the Kaffa. In the 19th century as stated by Kraft (87), the chief articles taken from Kaffa by the traders of Enarea were slaves and cotton textiles in large quantities. The traditional dress of the Kaffa has been described (68) as consisting of shorts "made of coloured cotton cloth ornamented with linear patterns; belts, 'sayo', of leather or 'ensat'—fibre; small girls wore front aprons of 'ensat'—fibre, 'manco', or beads, 'teko'. Men sometimes wore leather shirts, 'soro', and cotton loin-cloths, 'marto'. Both sexes wore cloaks; . . . capes of 'ensat'—fibre, and grass rain-cloaks, 'mekko'." The cotton "is spun by women with a wooden spindle, 'wofto', with a horn spindle-whorl. Cloth, from which clothes are made, is woven on a movable loom, 'maheno', set up in the courtyard of the homestead under a thatched roof. It is constructed like the Abyssinian loom (Am-

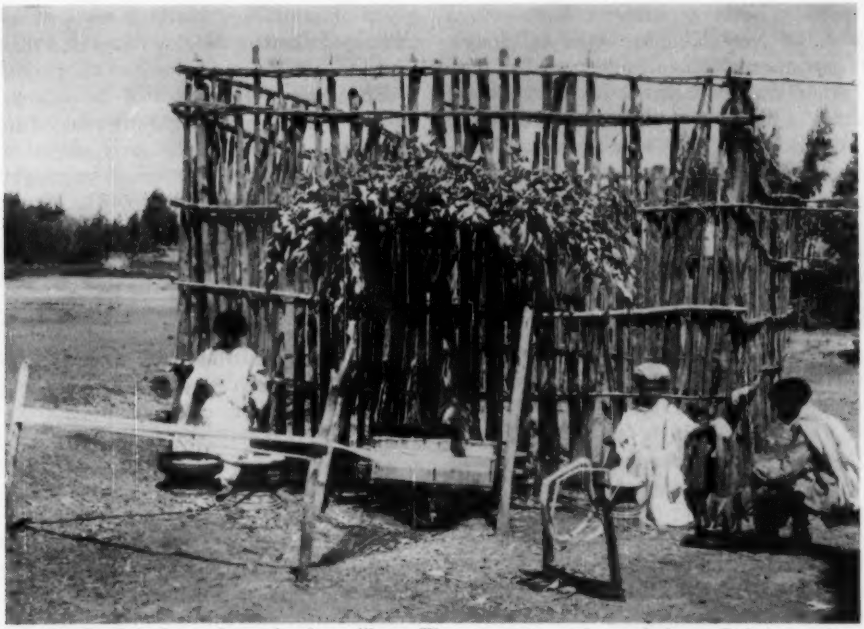

Fig. 8. Spinning and weaving in a village. The raw cotton and yarn is kept off the ground on special hand made baskets. Both the men and women wear the "shamma" wrapped around the shoulders, and sometimes as a hood over the head as with the weaver. The loom is the "pit treadle" type characteristic of the highlands.

haric 'arb). Weaving is done by men, who are called 'sammano' (Amharic 'sammane'), certain of the Manjo also practise weaving."

Spinning and Weaving

The history and origin of spinning and weaving in Ethiopia is not known and there is an almost complete absence of detailed studies. The evidence is very scanty but points to a situation essentially similar to that of the Sudan, and hence to links with both Egypt and India. The type of loom used in the Ethiopian highlands (Fig. 8) is that classified by Ling Roth (90) as the Pit Treadle Loom, which is the "common Hindu loom at which the weaver sits on the edge of a specially constructed hole in which his feet work the treadles, and is rather a method of working a loom than a distinct form of loom. It is met with largely in the green mountains of Oman, Arabia, half way between India and Africa." In Africa, itself, this type of loom occurs only "among the Gallas and contingent peoples" and also near Khartoum. The other type of loom of Ethiopia is the Horizontal Fixed and Heddle Loom which is found in various areas of East and North Africa and Madagascar, and occurs in Ethiopia only in the West.

The spinning of cotton in Ethiopia is similar in method to that of the Sudan. Crawfoot (40, 41) found strong resemblance between the Sudanese method of spinning cotton and that of flax spinning in Ancient Egypt. Links with ancient Egypt are also evident with other crafts and tools. Huntingford (68) has drawn attention, for instance, to the similarity

noted by Leser[1] between the Kaffa plough and the New Kingdom type of plough. There are undoubtedly other parallels with agricultural instruments that still require study (126, 145). The classification by Miss Bellinger[2] of Meroe textiles as being made with S—spun yarns which distinguishes them from the Z—spun textiles of other parts of the Near East (16, 48), may also be significant since linen fiber decrees S—spinning (115).

The suggestion has also been made by Laurent—Täckholm (89) that ensete was an important plant in ancient Egypt and that in the Middle Predynastic period a pictogram of the plant signified the idea of the 'south'. It is possible that the "byssus" of ancient Egypt, which provided the fiber for making the royal linen, may have been this plant (139). Ensete, therefore, must have been used for both food and fiber. The importance of ensete cultivation in southern Ethiopia at the present time has been recently described by Smeds (129), and Stiehler (135) has postulated that this plant was extensively cultivated in Ethiopia in ancient times by the original inhabitants of the region. Laurent—Täckholm placed the cultivation of Ensete in the Nile Valley in the "Neolithic wet phase" when increased precipitation in the highlands of Ethiopia must have caused extensive flooding (76). Ensete cultivation was abandoned as the gradual desiccation that followed set in.

There would appear to be, therefore, sufficient possibilities of links between Ethiopia and Egypt in ancient times to account for exchanges between the two regions of crafts and methods as well as cultivated plants. Midgley has stated that "at the very dawn of the historic period in Egypt we find the craft of the spinner and the weaver very highly developed in technique, manifestly, the early stages of the evolution of the loom must be sought back in the predynastic era" (48). If cotton cultivation is as old in Ethiopia as Ensete cultivation appears to be, and if ensete was an important food and fiber crop in Egypt in predynastic times, it is conceivable that spinning and weaving methods were introduced or developed very early in both regions. Weaving appears to have originated from basketry and matmaking (48, 90, 91). The Vertical Mat Loom of Central Africa, which may be indigenous to the continent, has many points in common with the ancient Egyptian mat loom. It may be, therefore, that the making of ensete mats in both regions in predynastic times provided the common craft out of which more elaborate looms were developed suitable for the weaving of the "royal linen", and later, also of flax and cotton.

[1]"Entstehung und Verbreitung des Pfluger," 1931. See also Simoons, F. J. (1958), "The Agricultural Implements and Cutting Tools of Begemder and Semyen, Ethiopia" (Southwestern Jour. of Anthro., Vol. 14, No. 4, pp. 386-406), for a discussion of the African or Arabian affinities of some agricultural tools used in northwest Ethiopia.

[2]Personal Communication, Textile Museum, Washington, D. C. See also Lamm (88) and Pfister and Bellinger (115).

Classification of Ethiopian Cottons

The first extensive collections of Ethiopian plants were made in the mid-19th century by Guillaume Schimper, who spent ten years in the country. Schimper's travels in Ethiopia were made under the patronage of the Botanical Society of Esslinguen, and his collections were first studied and classified by Hochstetter and Steudel in a series of publications between 1840 and 1844. Only one species of cotton occurs in these collections, namely *"Gossypium religiosum, Hochst,* in pl. Schimp., sect. II, no. 691 (non L)." (109, 118) which was collected in Tigre province in 1839. The exact location is given as: "Prope Dscheladscheranne in provincia Tigre cultum".[3]

[3]Specimen in the University of Cambridge Herbarium. Information communicated in correspondence by Mr. S. M. Walters, Curator. See also Aliotta (2), p. 69 and footnote.

The French Scientific Mission (118) visited Ethiopia in the years 1839-1843. The results of its work were published between 1845-1851 in six volumes (three parts) of which the last two volumes (Part III) is entitled Histoire Naturelle Botanique — Tentamen Florea Abyssinicae. This account of the botanical collections of the Mission was written by A. Richard, who studied the collections but was not himself a member. The work of the Mission also covered the geology, zoology, ethnology, history and customs of Ethiopia, and the whole account is a valuable record of Ethiopian natural history and of the life and culture of the country, including a description of the cotton cottage craft industry in Gondar. Richard's Tentamen Florea Abyssincae, although not a Flora, may be considered to be the first systematic attempt made to give an account of Ethiopian plants, since he was also able to include Schimper's collections and some of the lists and descriptions made by earlier travellers.

Richard described two species of cotton in one of which (*Gossypium punctatum*) he included the plant collected by Schimper previously classified as *Gossypium religiosum*. Part of the descriptions are as follows:

"GOSSYPIUM PUNCTATUM. Schum, et Thonn., pl. Guin., II, pag. 83; Guill. et Perrot, Fl. Seneg., I, 62." The species grows "in convalle fluvii Taccaze, in regno Tigreensi nec non in planitie provinciae Chire (Quartin Dillon, Schimper). Nomica abyssinica: Dut., Hout." Citation: Kew Herbarium and others: Schimper 691 and Quartin Dillon and Petit 267.

"GOSSYPIUM VITIFOLIUM. Lamk., Dict., II, 135; Cavan., Diss., VI, 166; DC., Prodr., I, 426." This species is also described by Richard as "Crescit et colitur in diversis Abyssiniae regionibus." Citation: Kew Herbarium and others: Quartin-Dillon and Petit 266.

The first hand accounts of Ethiopian natural history by European travellers began in the late 17th century with that of Charles Jacques Poncet, who visited the country in 1699-1700 (49). From 1633, when the Portuguese were expelled from Ethiopia, to the date of Poncet's visit, no first hand description of the country is known. But, although Poncet mentioned the use and cultivation of cotton in Ethiopia, he did not make collections or describe any plants. Poncet was followed by several travellers, with an interest in plants, specially Bruce, Salt, Fresenius, Hildebrandt, Schweinfurth and others. In the lists, collections and descriptions made by these travelers, cotton occurs in very few. The first is a specimen in a collection made by Hildebrandt in 1872 in Eritrea, and classified by Watt as *Gossypium Nanking* var. *Bani* Watt. (British Museum Herbarium: Hildebrandt 692). The second is a description of two species of cotton made by Harris (66) in an Appendix to the second volume of his book, which he named *Gossypium Efatense* and *Gossypium Gondarense*. Harris saw this cotton under cultivation in the region of Ankober and nearby lowlands, but apparently did not collect specimens. His description is as follows:

"Gossypium Efatense. Seeds completely covered with a close down. Cotton white: capsules 3-celled, 3-valved; flowers small, with a red fundus; leaves 3 to 5-lobed; lobes acuminated.

Gossypium Gondarenses. Seeds sprinkled with short hairs. Cotton white; capsules 3-celled, 3-valved; flowers large, yellow; leaves 3 to 5-lobed; lobes commonly obtuse." Harris observed both of these species as growing in the "sequestered nooks of the eastern face of the mountains of Shoa and in the valleys at the extreme foot of the range," and he states that the first type is indigenous to Efat, while the Gondar type was introduced.

Johnston (79) who visited the same area of Ethiopia as Harris, at about the same time, also mentions two types of cotton, "one very frizzly, with short fibre, was called Efatee tut, Efat cotton, the other, with a longer fibre, and more like unspun silk, was called Gondaree tut, Gondar cotton, and is by far the most superior, and none known to America or

Europe equals it in excellence." It is not possible to identify these two species accurately, and no attempt has been made by anyone up to now to do so. It might be deduced that they are *Gossypium hirsutum* var. *punctatum* for *Gossypium Efatense* and *Gossypium barbadense* for *Gossypium Gondarense.* Harris describes the general appearance of the plants and the agricultural merits of each as follows:

> "The Efat shrub varies, according to the locality and supply of water, from three feet in height to upwards of seven, and usually assuming the form of a pyramid, extends its lower branches to a width equal to the stature—the size of the leaves, and the soft and yielding nature of the stem, imparting a strong resemblance to the Bourbon cotton. Eight and nine inches in circumference are not unfrequently attained; and the advantages of a very productive crop twice in each year, the existence of the plant during five seasons, and the heavy return of the particularly fine wool during the very first, award to the species a most deserving pre-eminence.
>
> The indigenous plant of Efat is not, however, so much esteemed as that from Gondar, which, instead of rising tall and straight from the ground, assumes a spreading dwarfy appearance. The wool is considered superior, and the cloth produced is softer and more elastic, but its existence is limited to three years. Both are planted indiscriminately in the same field, although, when gathered, the crops are preserved unmixed; and after the fifth year the Efat shrub is cut over close to the ground, which is then ploughed up, and sown with wheat or other grain, when, on the removal of the harvest the young cotton shoots are well above the ground, and will yield during two further seasons.
>
> The seed, having been placed for some time in wood-ashes, is well rubbed with red earth before planting; and wherever the locality is favourable to irrigation, water is not spared. The pod, when ripe, is cut with a knife, the husk removed, and the wool deposited in a bag, with the utmost care to exclude extraneous matter. One full bearing bush produces twice during the twelve months between four and five pounds of raw stuff."

During the period between the publication of Richard's Flora and of Watt's monograph of 1907 on the cottons of the world (149), several new revisions of the genus were made, of which those of Parlatore (111) and Todaro (142) were the most important. The former author classified the Schimper plant as *G. arboreum* while the latter put it into *G. herbaceum.* Todaro was also the first to include Hildebrandt's collection, while Schweinfurth (123) also mentions Harris' plants, and he is apparently the only botanist to have ever done so. These older classifications of cotton as well as some very recent ones, specially that of Roberty, 1950 (120), and the intricate changes in nomenclature to which they have led, have resulted in some accounts of Ethiopian cottons in which the occurrence of "*G. arboreum*" is mentioned. (Fig. 9)

Sir George Watt in his 1907 revision of the whole genus, and in the subsequent publications of 1926 and 1927 (150) classified and described the following cottons from Ethiopia:

1. GOSSYPIUM ARBORETUM, Linn.
   "Schimper's Abyssinian plant, n. 691, which may be a hybrid of G. arboreum × G. Nanking." The specimen is also listed by Watt under G. Nanking Var. Roji.
2. GOSSYPIUM NANKING Var. Bani, Watt.
   "Hildebrandts n. 692 from Abyssinia, collected September 1872, seems a form of this plant."
3. GOSSYPIUM HERBACEUM, Linn.
   "G ? Punctatum, Richard." Quartin—Dillon 267.
4. GOSSYPIUM MEXICANUM, Tod.
   "E. Africa: Abyssinia, ex her. Tranqueville, n. 266."[1]
5. GOSSYPIUM VITIFOLIUM Lamk.
   "G. vitifolium, Richard." Schimper from "Choho".

Watt's 1907 re-classification excluded Schimper's plant from both *G. punctatum* and *G. herbaceum.* He determined the specimen, following Parlatore, as *G. arboreum* Linn., or possibly *G. Nanking* var. *Roji.* Richard's Quartin-Dillon and Petit

[1]The word should be Franqueville and refers to the Richardian (Quartin-Dillon and Petit) in the possession of Count Franqueville at that date.

Fig. 9. Perennial tree cotton grown at low altitudes (3,000 feet) near the Awash River Valley.

specimen became *G. herbaceum* L. However, in 1926 Watt again reclassified both specimens, this time as *Gossypium abyssinicum*, Watt, sp. nov., of which he said the following: "A coarse, thick, densely hairy plant met with in the East Sudan and Abyssinia. The following collections may be mentioned:—Sieber (ex. Herb. J. Gay) from Upper Egypt; Purdy, 61, Expedition Darfour, Barter from Nupe; Quartin-Dillon and Petit 267 from Abyssinia; Schimper, 691 from Abyssinia, leaves more drawn out and less tomentose than is customary, may possibly be a hybrid. This little known plant recalls very strongly the Indian *Gossypium obtusifolium* Roxb. var. *Wrightiana* race *Wagria:* it is far too hairy to be accepted as a form of *G. herbaceum* Linn." Earlier, before deciding on a species rank for these plants, he had written up the Quartin-Dillon specimen as *G. obtusifolium* Roxb. var. *abyssinica* Watt, ms, and on the Kew sheet of Schimper's collection he wrote: "I place this with some hesitation along with plants I regard as *G. obtusifolium* Roxb. var. *abyssinica*. The leaves are more drawn out especially the central lobe and the glands on all the veins below are striking differences."[1] Watt's *G. vitifolium* from Ethiopia refers to another sheet (probably Schimper) from "Choho" previously classified as *G. punctatum*.

Although Watt's monograph is still "the starting point for taxonomic studies in Gossypium," the publication in 1947 of the well known Final Report of the Genetics Department, Cotton Research Station, Trinidad (75), greatly changed and simplified the picture of the genus as pre-

[1] Personal communication from Dr. G. Taylor, Director, Royal Botanic Gardens, Kew.

sented by Watt. This Report incorporated a great deal of fundamental research work on the cytology and genetics of cotton in the years up to 1947, and also reviewed new collections and the important taxonomic changes made by Zaitzev (154), Harland (61, 64), Chevalier (28), and others (14, 119, 128, 151). However, there were no new types reported from Ethiopia. Some collections made by Italian botanists in Somalia in the years 1908 to 1925 were incorporated into the new classification (46). These collections showed the occurrences of *G. obtusifolium* Roxb. var. *Wightiana*, Watt and of *G. barbadense*. The result of the 1947 review of the genus as it affected the cottons of Ethiopia as classified by Watt, was as follows:

1. Schimper's n. 691: to *G. herbaceum* var. *africanum*.
2. Hildebrandt's n. 692: to *G. arboreum*, Linn.
3. Quartin-Dillon and Petit n. 267: to *G. herbaceum* var. *africanum*, Watt.
4. Franqueville n. 266: to *G. hirsutum*, Linn.
5. Richard's *G. vitifolium*: to *G. barbadense*.

In 1949, Hutchinson (71), in an important change, reclassified these two specimens of *G. herbaceum* var. *africanum*, Watt as *G. herbaceum* var. *acerifolium* Guill. et Perr. This species is therefore present in the Somalia river valleys, in southern Ethiopia (107), and in the Takazze river valley in the north, while *africanum* is absent.

Hutchison, 1950 (72), later suggested that the species *G. herbaceum* "is naturally divisible into five races, each occupying a distinct geographical area" instead of the previous division into a typical form and two varieties. This classification although covering "the major morphological distinctions" was "too incomplete to be worth retaining." The five geographical races were obtained as follows: "The typical form is divided into two, the central type of Iran and the neighboring countries (race *persicum*) and the small early cottons of western China (race *Kuluianum*). The present var. *acerifolium* is divided into race *acerifolium* in Africa and race *wightianum* in India. The South African form, race *africanum*, remains unchanged." Similarly, Wouters (153), following a suggestion made by Chevalier in 1939, combined the two varieties, *acerifolium* and *africanum* in one, namely "*G. herbaceum* L. var. *acerifolium* (G., P. et Rich.) Chev." and suggested two subvarieties as follows: "*Wightianum* Tod. (Watt, 1926; Hutch. 1932), Wouters, comb. nov.;" and, "*africanum* (Watt, 1926; Hutch. and Ghos. 1932) Wouters comb. nov." Roberty in 1950 (120) also put forward a new classification in which *G. herbaceum* is transferred to *G. arboreum*, and *acerifolium* becomes "*G. arboreum* var. *acerifolium* (Guill et Perr) Rob. comb. nov. equals *G. punctatum* var. *acerifolium* (Guill et Perr, 1830)." But he transferred Watt's *G. abyssinicum* to his *G. arboreum* var. *Wightianum* (Tod) Rob. comb. nov.[1]

These suggestions will be discussed later, and for the present, since the name of the North African form remains unchanged as *acerifolium* (i.e. *G. punctatum* var. *acerifolium* of Guill. and Perr., 1830), it will be clearer to follow in this paper the nomenclature of Hutchinson, Silow, and Stephen, 1947. On this basis, Hildebrandt's no. 692 is the only reported occurrence of *G. arboreum* in Ethiopia. The specimen is localized as follows: "Habāb. Am. Ufer d. Lepka".[2] Habāb is the tribal name of the trigiña speaking peoples of the coastal region of northeast Eritrea near the Sudan border. The region is closely linked ethnically and geographically with the Sudan, and Hildebrandt's specimen cannot be considered to be representative of the whole of Ethiopia. Fur-

[1]For a discussion of the validity of the species difference between *G. arboreum* and *G. herbaceum*, see Silow, 1944b (125) and Harland, 1936 (63). See also Chevalier (30).

[2]Information supplied by A. W. Exell, Deputy Keeper of Botany, British Museum.

thermore, the specimen is classified as *G. arboreum* race *indicum*,[1] which is of relatively recent introduction to northeast Africa. It is a significant feature, therefore, of all the collections so far made that the only Asiatic species represented is a perennial form of *G. harbaceum* var. *acerifolium*, now occurring in two distinct areas in the north and southwest of Ethiopia.

Watt (1907) in discussing Father Alvarez's observation as reported by Pory that there is "great plenty of cotton whereof they make cloth of divers colours," commented as follows: "That remark was made of Abyssinia in 1520, and possibly had reference to *G. herbaceum* or *G. arboreum*, not *G. punctatum*, for the simple reason that no authentic specimen of that species has as yet been collected in Abyssinia. The plant named *G. punctatum* by Richard is, I believe, *G. herbaceum*." Since neither *G. hirsutum* var. *punctatum* or *G. arboreum* appear to have been cultivated in Ethiopia on any scale in the past, if at all, it seems very likely that cotton growing in Ethiopia in the early 16th century was based upon *G. herbaceum* var. *acerifolium*. Furthermore, Watt also suggested, with reference to the Schimper and Quartin-Dillon specimens (later, 1926, reclassified and renamed by him *G. abyssinicum*, Watt, sp. nov., now transferred to *G. herbaceum* var. *acerifolium*), that this cotton could not be of recent introduction and "would appear to be indigenous to Abyssinia since it has there distinctive vernacular names such as hont." Similarly, Roberty (120) has suggested that Schimper's Ethiopian specimen indicates that variety *"acerifolium* (Guill. et Perr.) Rob. comb. nov.," is a "forme centrale . . . . . originaire d'Abyssinie et non du Senegal." The suggestion that Senegal is the place where this variety might be indigenous was made in 1948 by Wouters (153), but this region was only a part of a much larger indigenous range. Wouters described the range as follows: "Cotonnier d'origine africaine, indigene du Soudan au Niger et en Senegal et en Zambézie." The word *"hont"* mentioned by Watt, is probably a misprint for the word *"hout"* given by Richard for one of the two local names for cotton in the area where this plant was collected: "Namica abyssinica: Dut, Hout." A similar error also appears to have been made by Richard with the word *"dut"* which probably stands for the Amharic *"tut."*[1] Hout is an Agao word, the language of the peoples occupying the Takazze river valley. Other names for cotton in Ethiopia are *hutto* in Kafa, *futta* in Sidama,[2] *tido* in Janjero, *Gerb* in Galla, and *Suff* in Somali (68). Of these the first three are related (22).

Watt's suggestion that there are "distinctive vernacular names" for cotton in Ethiopia was undoubtedly correct, but of perhaps even greater interest as evidence that this cotton may be indigenous to the region is the fact that most of these names occur mainly in the old Hamitic langauges of Ethiopia and refer specifically to *G. herbaceum* var. *acerifolium*, which is the cotton of these Hamitic speaking areas (22, 35). Agao people inhabited in the past most of the northern and central Ethiopian plateau, and they are considered to be "the most ancient population of the country" (141). The indigenous Hamitic Agao in time fused with the Semitic immigrants from South Arabia (the main groups are thought to have come around the 7th century B. C.), who had settled amongst the Agao, to form eventually the Semitic-Hamitic Ethiopian of the present day. Pockets of the descendants of the original Agao population still remain in a few places in the north, west, southwest,

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[1]Information supplied by A. W. Exell, Deputy Keeper of Botany, British Museum.

[2]Personal communication from Professor W. Leslau of the University of California at Los Angeles.

Lake Tana, and Takazze valley regions of Ethiopia. In southern Ethiopia the indigenous Hamites are now represented by a variety of peoples, who were never absorbed by the Semites, and still speak Hamitic languages. These indigenous southern Hamites occupy the south and south-western regions of Ethiopia and are now completely cut off from the northern Hamites by intervening Semitic peoples and by the much later immigration of Gallas (25). However, there are still some islands of Hamites along the western and northwestern parts of Ethiopia (the Mao or Amphilo north of Gambela, and the Burgi in the Blue Nile valley near the Sudan-Ethiopian border), and it is certain that at one time southern and northern Hamites were in close contact (59, 141). *G. herbaceum* var. *acerifolium* occurs separately amongst both the Hamitic Agao of the north, and the Hamitic Sidama tribes of the south. In both areas the plant is a perennial, as is also the case in the Uebe Shebeli valley where settled farmers of Bantu stock grow this cotton under irrigation. Neighboring tribes of mixed Hamitic-Nilotic stock, especially the Burgi and Konso in the south, also cultivate cotton of this species, while Galla and Amhara farmers cultivated mainly *G. hirsutum* var. *punctatum*.

In addition, one of the most significant facts that emerge from the study of the cottons of the Ethiopian region, as already mentioned, is the absence of *G. arboreum*. Ethiopia is, therefore, an exception to the rule that "*G. arboreum* occurs in all the areas of Africa from which *G. herbaceum* has been recorded, and in some from which the latter is absent" (75). Perennial *G. arboreum* occurs in several regions of Africa where it is represented by races *soudanense* and *indicum*. The former is found in the Sudan, Somalia and West Africa, and the latter mainly along the East African coast. It would be expected, therefore, that *G. arboreum* might be present in Ethiopia at least as frequently as in the Sudan. The possibility that it was once cultivated and has now disappeared is made very unlikely by the complete absence of remnant cultivations even of *G. arboreum* race *soudanense*.[1] A more likely explanation would be that *G. herbaceum* var. *acerifolium* was already present and that this made unnecessary the cultivation of the inferior *G. arboreum*.

It is thus very likely that the suggestion made by Watt and Roberty that *G. herbaceum* var. *acerifolium* is indigenous to Ethiopia is correct on the basis of the available botanical and historical evidence. The populations of this variety so far discovered in Ethiopia, like the number of specimens in herbaria, are very small indeed and need to be studied in detail. Very little can as yet be said, for instance, on the variability and other characteristics of the Ethiopian plants. It is apparent, however, from observations on plant habit, range of adaptability and some morphological features, that these populations are markedly variable, specially in the south. And the historical evidence shows unquestionably that the cotton grown in the past was a perennial. As Hutchinson (69) has pointed out: "All the old records agree in stating that the early cultivated cottons of India and Abyssinia were perennials and not annuals." Furthermore, Chevalier, as stated by Hutchinson in 1938 (69) "is emphatic that the types of *G. herbaceum* var. *africanum* and var. *frutescens* and their intermediates, with which he is familiar, are not wild in the French African colonies." There is little doubt therefore that these types in West Africa are relatively recent introductions, probably made by the Arabs (97). The routes across the African savannah followed by the Arabs to reach west Africa were also used by returning Moslem pilgrims. *G. hirsutum*

[1]It should be noted that Silow (125, Appendix) included *G. abyssinicum* Watt. in this race. See also Hutchinson and Ghose (74).

var. *punctatum* probably reached Ethiopia from the west by this means. The date when *G. barbadense* reached Ethiopia is not precisely known, but it appears to have been before 1820 (107).

The earliest indication of the use of cotton in the Old World is that provided by cotton fabrics discovered during the excavation at Mohenjo-Daro and dated from about 3,000 B.C. (60). In the New World, the earliest record is that of an archeological level containing cotton in the Viru Valley of Peru, dated approximately 5,000 years ago (17, 23, 103). These findings have increased the probability of man's intervention in the development of cultivated cotton at a relatively recent time (75, 130), but the role of Africa in this process, which may have been very important, still remains obscure. The wild cottons of Africa and their relationships and distribution provide some important evidence about this problem.

Two species of wild cottons have been collected from two separate regions of Ethiopia, one in the north (Eritrea) near the Sudan border, and the other in the southeast near the Somaliland border. *G. anomalum* was reported by Steuder, Baccari, Hildebrandt and Schweinfurth from the Bakara river valley. The specimen seen by Todaro and collected by Baccari in 1870 is described as: Piante del paese dei Bogos (Abissinia Settentrionale) No. 215—Gossypium - Abita Boggia - Vallate del Baraka" (2). *G. somalense* occurs in the Sudan and in the Somaliland-Ethiopian border (24, 96). It is of special interest to note that wild species are absent from the whole of the territory between Somalia and the Sudan. As a result, a marked discontinuity exists in *G. somalense*.

This barrier between the two regions has been discussed by Knight (84). He suggested that since the variability of *G. somalense* is greatest in Somaliland, this region is the center of origin of the species. Douwes (44) assigns the center of variability of the whole sections Stocksiana to this region. However, in the absence of Stocksiana from Ethiopia and Eritrea "the link between Somaliland and Kabbashi-Fada (Sudan) occurrences is vague" (84). The spread from Somaliland to the Sudan must have occurred in any case a very long time ago since *G. somalense* in the Sudan "has not changed appreciably since the last pluvial period, despite its spatial isolation in a series of localized groups of plants." It is reasonable to suppose, therefore, that *G. somalense* and undoubtedly also *G. anomalum*, did occur on the Ethiopian plateau in the past before the last pluvial period in Africa ("Makalian and Neolithic Wet Phase") (33, 34).

G. anomalum was at one time classified in *Cienfugosia*, but was transferred to Gossypium by Chevalier (27) and Skovsted (127). *Cienfugosia Welshii* (T. Anders) Garcke has its area of high variability in Somaliland (32, 70) and a species of *Cienfugosia* has been reported as growing in southern Ethiopia by Cufodontis (42). *G. anomalum* has an extensive distribution in Africa, and it overlaps that of *G. somalense* in the Sudan. Its occurrence in northern Ethiopia up the Baraka river valley, in the highlands of Eritrea, is a remarkable example of its capacity to spread. The Bogos people of this area, like those of the Takazze, already mentioned, are also Agao (35, 141). Variability within the species is negligible although some "hidden variability is released upon hybridizing material from widely separated localities (Saunders, in press)".[1]

Origin and Relationships

The possibility that *G. herbaceum* var. *acerifolium* is indigenous to Africa, specifically to the Ethiopian region, cannot be fully considered without reference to the

[1]See Saunders, J. H. (1959) "The Wild Species of *Gossypium*", Emp. Cott. Grow. Rev. Vol. 32, no. 1, pp. 14-20.

problem of the African origin of the diploid Old World cultivated cottons. The hypothesis put forward by Hutchinson, Silow and Stephens in 1947 that cultivated cottons arose in the Indus Valley has recently been rejected by Hutchinson (73) and an alternative area suggested in Africa. Watt, in 1926, had already pointed to the many suggestions apparent in his extensive studies of Old World cottons of "India having derived some of its stocks from Africa," and Zaitzev (154), Ayyer (8, 9), Silow (125) and others also indicated that *G. herbaceum* probably originated in Africa.

The cytogenetic evidence shows that the closest wild relatives of the cultivated Old World cottons are to be found in the group Anomala of Africa, in particular *G. anomalum*. Dauwes (45) has recently shown that the wild species *G. areysianum* from southern Arabia belongs in the group Stocksiana and not to the Anomala. Hence the Anomala is confined to Africa and does not extend into Arabia as previously thought. *G. herbaceum* var. *africanum* it is thought may be the earliest derivative from the Anomala, and the assumption is therefore made that "the cultivated cottons of the species *G. herbaceum* were derived by selection from the perennial wild *G. herbaceum* var. *africanum* of the South African bushveld" (75). The possibility, however, that *G. herbaceum* var. *africanum* is not truly wild but is secondarily cultivated, and hence possibly an introduction, cannot be overlooked.

The precise region of Africa where the cultivated Old World cottons first arose is still a matter of much conjecture. East Africa and the Sahara have been suggested in the past (31), and Hutchinson has recently postulated southern Africa. However, assuming that the development of cultivated cotton occurred as a result of domestication by man, it might be expected in the first place that this occurred in a region where other oil and fiber plants were probably also domesticated in Africa. The most important region in this respect is unquestionably Ethiopia (55, 86, 121), where Vavilov placed one of the oldest of his centers of variability of cultivated plants. If *G. herbaceum* var. *acerfolium* is indigenous to this region, it is of special interest to examine the possibilty that it was also here where cultivated diploid cottons arose.

In postulating that the cultivation of cotton originated in southern Africa, Hutchinson pointed to the suggestive occurrence of both *G. anomalum* and *G. herbaceum* var. *africanum* in that region. In addition, he suggested that this latter type, which has hitherto been regarded as being secondarily cultivated, is in fact, a truly wild cotton. In support of this view, he adduced the work of Pearson (112) on the evolution of *Diparopsis castanea*, the Red bollworm. The evolution of this insect, "endemic in southern Africa, can only have taken place on *G. herbaceum* race *africanum*, and it follows that *G. herbaceum* race *africanum* must have been established in southern Africa during the whole evolutionary history of the pest. It must, therefore, be truly wild and not a recent escape from cultivation" (73). However, Pearson, himself, has disagreed with this interpretation of his data. "The suggestion that the distribution of an insect must necessarily coincide precisely with that of the plant which is its primary host is one which I find difficult to accept" (113). Thus, although africanum cottons may well be wild, the work on *Diparopsis* according to Pearson, "provides no wholly convincing evidence to support the theory that they are." The problem of what precisely constitutes a wild ancestor, as is the case with other cultivated plants (4, 137), is still debatable in many respects. Konstantinov (85), for instance, claimed that it is not really possible to define what is a cultivated as distinct from a wild ancestor cotton, and that the boundary between the two must always remain indefinite. The problem of

possible wild New World tetraploids is even more difficult (65) and Hutchinson, Silow and Stephens (1947) considered that all the reported occurrences of spontaneous tetraploid species could be explained as being escapes from cultivation.

In view of these and other considerations it is suggested, as an alternative hypothesis, that present day *africanum* and *acerifolium* may be regarded as the separate descendants of a common ancestral cultivated stock. Each variety arose separately from it by geographical differentiation and selection by man. The primitive ancestral stock must have once bridged the territorial gap that now exists in the distribution of the two varieties in Africa, and may have also been extensively grown in the northern and western parts of the continent, and possibly in Asia. Hutchinson (71) hinted at this possibility in a reference regarding the possible introduction of *africanum* into Africa: "There is nothing to show the source whence it came, or the time of its introduction, but primitive perennials, that might well represent a type ancestral to both *acerifolium* and *africanum*, are still cultivated in the Mekran region of southern Baluchistan (Ansari, 1941)." It may also be that this stock also spread from the African continent across the Atlantic to America, where is gave rise to the New World 26 chromosomes cultivated cottons. This possibility is in general in closer agreement with the Red bollworm situation than appears to be the case with *africanum* alone. Thus, the theory put forward by Pearson would "regard Sacadodes in the New World and Diparopsis, in Africa, as having a common derivation in association with Cienfugosia, which is also confined to the tropics and sub-tropics of Africa and the New World" (93, 112). Ayyer (9), Abraham and Ayyer (1) and Gerstel (51, 52, 53) have suggested, on the basis of anatomical and cytological studies, that *G. herbaceum* is closer than *G. arboreum* to the tetraploid New World cottons. Gerstel also considered from interspecific crosses that the chromosome end arrangement of *G. herbaceum* was "the most primitive because it was shown to be identical with that of the primitive wild species *G. anomalum*" (19). On this evidence, he stated that "the possibility that a species apparently centered in Africa may be closer to the New World cottons than the now largely Asiatic *G. arboreum* should be taken into account in the further discussion of the origin of the New World amphidiploids. It might be considered to weaken the hypothesis of a recent Pacific transfer of an Asiatic component of the amphidiploid hybrids, which was tentatively pronounced by Hutchinson, Silow and Stephens (1947). The possibility of an Atlantic transfer should perhaps not be entirely neglected" (51). The possibility of a trans-Atlantic transfer of such a primitive cultivated and intermediate stock would also account for the fact that "there is no evidence that any existing 13-chromosome species is exactly like those involved in American tetraploid species (14, 98). At the same time Stephens (132, 134) found that the leaf shape development in *G. anomalum* is transitional between Asiatic and American types. The chromosomes of *G. anomalum*, as first reported by Skovsted (128), are intermediate in size between those of the cultivated Old World cottons and those of the American diploids. The Asiatic diploid parent of the New World tetraploids, it would be expected, was closer to *G. anomalum* than the more developed present day cultivated Asiatics.[1]

The problem of the origin of this primitive cotton is the problem of accounting

[1]There is an extensive and well-known literature on the general problem of trans-Pacific contacts (136). Silow (1953) discussed the situation with regard to cotton at the Seventh Pacific Sci. Congr. (Proc. **5**: 112-118): "The Problems of Trans-Pacific Migration Involved in the Origin of Cultivated Cottons of the New World." See also Stephen (133).

for the enormous variability of the cultivated cottons in terms of evolutionary success (70, 131). In the general region of northeast Africa (the Sudan, Eritrea, and the Horn of Africa), and southern Arabia, is to be found the only concentration (four species) of wild cottons of the Old World.[1] All these species, with the exception of *G. anomalum*, belong to the section Stocksiana. Only *G. somalense* of this section has spread to some extent and it overlaps *G. anomalum* in Somalia and the Sudan, but does not occur in the Ethiopian Highlands. Dauwes (45) has suggested that if it is assumed "that the present centres of distribution of the two sections indicate the areas from which they have arisen, it would mean that *G. somalense* has spread from the east and *G. anomalum* from the southwest, thus converging in north central Africa." This convergence, in the view of Hutchinson, Silow, and Stephen (1947), is more likely to have been from areas situated in north central Africa and Indo-Arabia.

In both cases the area of convergence is presumed to include the south and southwestern region of Ethiopia. This region is climatically distinct and is also a "disturbed habitat" in which geological change, including extensive vulcanism, has occurred on a large scale (46, 101, 108). Consequently, the flora in general, as recently demonstrated by Gillet (54), is different from that of northern Ethiopia and somewhat closer to that of Kenya and Uganda. The separation between the wild species of cotton now found in Somaliland and the Sudan may have been a consequence of these geological changes. It is suggested that it was in this region where the selective effects of the Ethiopian plateau provided the conditions for the accumulation of variability in the wild progenitor of the cultivated cottons as it spread into the open habitat. Once the species became variable its capacity to respond to further selection by man was greatly increased (70).

Hutchinson in 1954 (73) pointed out that it is necessary to suppose that the first A genom (Old World cultivated) species was allopatric to the early B genom (Anomala) species, and that the A genom species arose in areas "adjacent to but not within that occupied by the early representatives of the Anomala." In addition, the spread of the early A genom cotton into more mesophitic habitats must have begun very early. These conditions are also fulfilled both geographically and ecologically by the region of southern Ethiopia. The hypothesis is therefore put forward that the A Genom cotton was gradually evolved in this region as an ancestral cultivated stock which spread into other regions in association with man.

The occurrence of late climatic changes in the African continent, culminating in the "Neolithic wet-phase" and more recent subsequent desiccation, as already mentioned, is sufficiently well established; and evidence of the effects on the early cultures of Africa continues to accumulate (33, 34, 76). One of the consequences of these changes, insofar as cultivated plants in Africa is concerned, may have been one of general and widespread recession of cultivation from the gradually desiccating to the moist regions. Wild plants, of course, were also affected. In the Sudan, for example, *G. somalense* (which is possibly more xerophytic than *G. anomalum*), is now found on jebel tops separated by desert. This is a result of "its recession to the jebels in the era of desiccation following the last pluvial period, which occurred about 4,000 years ago" (84). At least three of the important and probably indigenous cultivated plants of Ethiopia, namely coffee, *Ensete ventricusum* and sorghum appear to have been affected by this process (135). As this happened, only

[1] In a recent Note (1958), Hutchinson, Sir J. B. and Lee, B. J. S. have reported a new species of *Gossypium* from Tanganyika (Kew Bulletin. Notes from the East African Herbarium, VII).

the types already adapted to the more favorable situations and new selections could survive. Furthermore, it is likely that a plant which at first spread rapidly and widely into a tropical region might be exterminated as tropical pests become adapted to it so that it survives only in isolated places.

It was probably at this time that the two present types of perennial indigenous cottons still found in Africa were differentiated in isolation, as cotton cultivation receded and the ancestral form disappeared. The ecological barrier between acerifolium and africanum at the extreme range is such that the two forms are still strictly confined to their original habitats. In addition, this geographical and ecological separation is reflected in genetic differences, the more important of which, as reported by Silow (124), "appear to be associated rather with geographic distribution than with the acquisition of the annual habit." In addition, in *G. herbaceum* (unlike *G. arboreum*) "geographic separation is associated with morphological distinction. Thus the southern africanum cottons are strongly monopodial, with small thin leaves and short coarse lint. The African and Western Indian frutescens types have larger, more rugose leaves, and are intensely hairy." Intermediates between the two varieties occur in several areas of Africa, but not within or adjacent to the regions where each is indigenous and still represented. These intermediates are the result of the convergence of the two varieties as each spread in relatively recent times into areas once probably occupied by the ancestral stock. In the north the mixture is so complete that Chevalier (28) considered these intermediates to be a new variety.

A similar process may have taken place in the differentiation of the group of sorghum varieties in west Africa from those of Ethiopia, and of different types of *Coffee arabica* in different regions of Ethiopia. Thus specimens of coffee collected by Schimper and Quartin Dillon in northern Ethiopia were classified by Chevalier (26) as *C. arabica* var. *Abyssinica* Chev., and were considered by Spaletta as "the original type of all coffees" (138). However, the so-called "wild coffee forests" of Ethiopia are situated at present in the south and southwest of the country, and it is possible, according to Von Strange (137) that most of these, if not all, are secondary. With regard to ensete, its occurrence in predynastic Egypt, as already mentioned, has been suggested by Laurent-Täckholm, and it is possible that it was also grown in northern Ethiopia in the past. As the wet-phase ended, ensete "withdrew to the south, to its proper home in Ethiopia, becoming extinct in Egypt" (129).

These examples of discontinuity in distribution of some indigenous cultivated plants of the Ethiopian highlands, leading to morphological differentiation, support the conclusion of Silow regarding *G. herbaceum:* and also suggest the role that the special geographical conditions of Ethiopia, specially altitude, may have played in the later development of the annual habit in this species. In general, it appears to be a common factor in several cottons that the annual habit has arisen principally in highland regions by the mechanisms of photoperiodic response, and facultative shedding of buds found in perennials which ensures the correct timing of the onset of the crop. Thus in Western India, *G. herbaceum* "is represented by var. *acerifolium,* which is an annual, but which still carries an important character usually associated with the perennial habit. So long as wet weather continues, all flower buds are shed at a very early stage" (75). Hence, Hutchinson continues, "fruiting occurs in dry weather, but since an annual plant fruits only once, the facultative shedding mechanism is no longer essential, and in most annual cottons the fruiting branches appear at the

Fig. 10. Perennial cotton at high altitudes (5,000 feet) in full production. The plant is typically low and bushy. It is only in well-sheltered areas and lower altitudes that it grows taller.

right time to ensure cropping in the dry season." It is significant in this respect that the climatic conditions in most of Ethiopia, especially the north, owing to the altitude together with a monsoon type climate (47), are such that in the development of a suitable cotton, selection for the "annual" habit must have been important from the beginning. However, as previously discussed by this author (106),[1] the cultivation of annual entirely rain-grown cotton in the northern Ethiopian highlands is an extremely difficult task, because the main rains which come in June to September are followed by cold night temperatures in October to November which retard growth considerably. Consequently, the practice with some peasant-grown cotton, even when using introduced annual types, is to grow it on a bi-annual cropping basis. Selection is strongly in that direction. (Fig. 10)

The climatic conditions in southern Ethiopia, on the other hand, are such that there is no marked check on growth during the colder months of the year. Winter in the South is less severe, the rainy season is double (maxima in April and October), and the length of the summer day is shorter. Perennial cotton is grown for many years under these conditions. Insect pests and diseases, however, are severe in this region and the tendency is to grow cotton at high altitudes to escape them. It would thus seem reasonable to suppose that the perennial type of Ethiopia first developed towards a bi-annual habit, and that the annual habit was developed from it by further selection in climatic conditions, such as those obtaining in the Iranian highlands, where a

[1]See also Seljaninov, "Agroclimatical zones of Abyssinia." Bull. App. Bot. Gen. and Plnt. Breeding. **22** (5) : 489-522.

short growing season occurs (6)[1]. Ethiopian *acerifolium* is on the whole, as described by Watt, a "warm temperate" type (149), still found growing mainly between 3,500 and 4,500 ft. It is possible that *G. herbaceum* var. *acerifolium* of Ethiopia is thus indigenous to this region and also, as Watt suggested, a more primitive and distinct race: *abyssinicum*, as described by him.

The cotton of Mohenjo-Daro (3,000-2,750 B.C.), may have been *G. arboreum* (Gulati and Turner, 1928). The available evidence shows that *G. arboreum* possibly arose in cultivation by differentiation from *G. herbaceum* (73, 75). On genetical and morphological grounds (73, 125), the closest resemblance, however, is that between perennial *G. arboreum* race *indicum* and perennial *G. herbaceum* var. *acerifolium*. Gulati and Turner also showed that the Mohenjo-Daro cotton was more like *G. arboreum* race *soudanense* than *G. arboreum* race *indicum* of peninsular India. The former type is the oldest. In view of these facts, *soudanense* could not have been differentiated from *acerifolium*, and Hutchinson (73) has suggested that wild *africanum* was taken north by gold traders at a very early date: "Thus the most primitive cultivated herbaceums are to be found on the coasts bordering the great Indian Ocean trade route by which it must be supposed that the introduction of their wild ancestor from southern Africa was affected." The area of introduction where the differentiation of cultivated herbaceum took place "may be taken to be Arabia or the coasts of Persia and Baluchistan," and the area where the primitive arboreum arose was that in which the Indus civilization developed.

Our knowledge of the ancient history and pre-history of Ethiopia, and indeed of Africa south of the Sahara, is still in its infancy. Nevertheless, some evidence already exists of megalithic and neolithic cultures in Ethiopia (10, 33, 81), and of possible links between them and those of other parts of Asia and Africa (7, 13, 21, 34). Hence the available knowledge already points in many respects to the increasing importance of this region for future work on the early development of man and of his crops and animals (86). The region was undoubtedly, in ancient times, both an important center of plant domestication and dispersal (129, 144), and "a gateway to Africa" from the East. In this second respect, there were probably two main routes of penetration, one in the North (121, 126), and one in the South (107). At the same time the diffusion of peoples from this region is known to have taken place. Wilson (152) has noted the evidence of an ancient civilization in the Rift valley characterized by the construction of terraced structures. These structures, as pointed out by Jensen (77, 78) "are found indeed among many of the old peoples of southern Abyssinia." He states that such peoples were mainly "ancient food-cultivating ('planter') folk and mountain-dwellers, who preferred fairly elevated sites for their settlement, as at Inyanga." Although they could not be the earliest food-cultivators, Jensen believes that the Konso and the Inyanga of southern Ethiopia are remnants of peoples who also had similarities with "the old negritic peoples of the Sudan extending right to West Africa." He considers that the stone symbols of southern Ethiopia described by Azais (10), which are also found in Southern Rhodesia, represent common ancient rituals amongst related peoples of both regions.

[1] Cotton is by no means an isolated example of contacts by such a route between Ethiopia and Asia. In discussing the pea (Pisum) in Ethiopia and Afghanistan, Govaror, for instance, stated that: "One of the possible ways by which the Abyssinian forms came to Afghanistan is through Arabia, Syria, Mesopotamia and Persia." (Govaror, L. I., "The peas of Abyssinia. A contribution to the problem of the origin of cultivated peas" in Bull. App. Bot., Gen. and Plnt. Breeding **24** (2): 420-431. 1929-30). See also Takahashi (140).

However, Wainwright (147, 148), and other authors, believe the connection to be of later date.

The situation with regard to the development, spread and history of any particular plant in the Ethiopian region is clearly likely to be extremely complex. This is well illustrated by the problems arising from consideration of the relationships and history of such ancient cultivated plants of Ethiopia, and other regions of the world, as wheat and barley (140, 144). With respect to cotton, it is of special interest to note that several crop plant genera share the Ethiopian and Indian centres of origin (144), especially *Andropogon, Cicer, Dolichos, Vigna, Sesamum* and *Brassica*. There is every possibility, therefore, that cultivated cottons of the species *G. arboreum* were first differentiated in the Indian region directly from the introduction of an ancestral cultivated type of Africa first developed in Ethiopia. The magnitude of the differences between perennial *G. arboreum* race *soudanense* and *G. herbaceum* as compared to those within *G. herbaceum*, are such that the above possibility seems more likely than the evolution of *soudanense* from a more primitive *acerifolium*. Similarly, the possibility of such an ancestral cultivated African stock occurring along the territories linking East Africa with Arabia, Persia, Baluchistan and India eliminates the need to postulate a northern transfer of wild *africanum* by traders at a date sufficiently early, before 3,000 B.C., to allow for the development, directly from the wild, of *G. herbaceum* and later of *G. arboreum*. These suggestions, in the absence at the present time of more precise data, must remain as tentative indications of possible directions for future research. It seems certain, however, that a much greater weight will have to be given to the Ethiopian region than has been possible in the past.

Acknowledgments

I am grateful to Sir Joseph Hutchinson, F.R.S., School of Agriculture, Cambridge University, and to Dr. Edgar Anderson, Missouri Botanical Garden, St. Louis, for reading the typescript and for many valuable comments and assistance. I am also indebted to the University of California, Berkeley, for facilities provided, in particular to Dr. H. G. Baker, University Botanical Garden, Department of Botany.

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Alkaloids of the Apocynaceae

Of the 200 alkaloids in the relatively well-studied Apocynaceae, only 75 have had sufficient chemical investigation to permit their structural identity. Nonetheless, certain correlations are discernible and may be used by the plant chemist as first approximations of the types of materials he may expect in the analysis of previously unstudied genera.

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Introduction

The renaissance in phytochemical research which has occurred during the last decade has produced a voluminous literature on plant principles which has become of increasing significance to a number of interrelated disciplines. The botanist, plant physiologist, and chemist have become equally concerned with the possible correlations between the structures of plant principles and the position of the plants within taxonomic groups.

Erdtmann's work on the conifers (31) is an excellent example of this type of study. The plant physiologist and organic chemist have proposed mechanisms for the biogenesis of plant principles, many of which can be reproduced under laboratory conditions. Recently Hegnauer (49) has summarized a number of possible biogenetic pathways leading to the alkaloids and attempted to relate these, in a broad sense, to the plant families in which they may be assumed to operate. Wenkert has criticized some of these (139).

The medicinal chemist, with his new-found colleagues in the fields of botany and folk-lore, has undertaken a search of the plant kingdom of greater intensity, perhaps, than the classical phytochemical investigations of the 19th century. His hope is to find not only new drugs *per se*, but starting materials for his syntheses and novel structures that may lead to new pharmacologically active materials. If, indeed, there is a correlation between chemical structure and plant source it would be an extremely valuable tool in these investigations.

With the possible exception of Wehmer (138) which is now out of date, most texts do not approach the plant principles from the point of view of their distribution in the plant kingdom. A recent study by Willaman and Schubert (141) leads the interested worker to statistical facts concerning the alkaloids. There is, however, no ready reference to the types of structures to be anticipated by "alkaloid hunting" in the specific botanical subdivisions. For many of these the available chemical information is, at best, scanty.

From many points of view it would be of interest to examine the relationships between chemistry and taxonomy. Because of the recent popularity of the Apocynaceae as a source of a number of interesting drugs we have compiled the known information on the family. Willaman and Schubert (140) previously listed the alkaloids without reference to chemical details. While this manuscript was in preparation, an excellent review by Bisset (10) appeared. This gives the medicinal uses of the genera and, through what is largely a botanical approach, deals in some detail with the thorny problem of synonymy within the family.

Study of the reported data in the fol-

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lowing tables suggests that there is obviously much more chemical work to be done before valid generalizations may be made on the relationships between taxonomy and alkaloid structure. Of the 200 alkaloids in the relatively well-studied Apocynaceae, only 75 have had sufficient chemical investigation to permit their structural identity, and it is probably safe to say that much of this progress has been made in recent years as a result of the economic importance of *Rauvolfia serpentina.*

Clearly it is not intended to relate mushrooms to maples simply because the same type of chemical compounds has been isolated from each (Pachter, I. J., et al., Indole Alkaloids of *Acer saccharinum,* Jour. Org. Chem. **24**: 1285. 1959). Nor is there any reason to suppose that there must be a correlation between alkaloid structure and taxonomic position. Nonetheless, certain trends are discernible and may be used by the plant chemist as first approximations of the types of materials he may expect in the analysis of previously unstudied genera.

Assuming the classification of the family according to Pichon as given in Bisset (10), it is comforting to the chemical taxonomist to note that ⅓ of the known genera of the Tabernaemontaneae thus far studied contain alkaloids of the same type (E-3). These are, incidentally, found only in that tribe of the family and it is likely that these will be found in other reported alkaloid-bearing genera of the tribe, e.g., *Peschiera, Anacampta, Stenosolen.*

While this compilation was in progress two reports appeared on the alkaloids of *Conopharyngia.* Dickel, et al. (Jour. Am. Chem. Soc. **81**: 3154. 1959) reported the isolation of 3β-hydroxy-20α-amino-5-pregnane β-D-glucoside from *Conopharyngia pachysiphon.* On the other hand, Renner et al. (Helvet. Chim. Acta **42**: 1577. 1959) found the typical alkaloids of the Tabernaemontaneae in *Conopharyngia durissima,* a much more reasonable chemotaxonomic finding. The identity of Dickel's plant material is thus open to further confirmation; the alkaloid is related to those of *Holarrhena* which genus would appear, in a chemical classification, closer to *Funtumia* than it now stands in the Alstonieae where the carboline alkaloid types predominate.

Whatever the botanists' reasons for separating *Catharanthus* from the genus *Vinca,* it may be seen that these are very close chemically with alkaloids of types B2a, B4a, and E-1 common to both genera. Similarly, on the basis of recent knowledge (20) there is little chemical distinction between *Ochrosia* and *Bleckeria* and the finding of reserpine in the latter genus[1] tends to confirm the close relationship to *Rauvolfia.*

The reported occurrence of only one simple indole in the Apocynaceae to date is of sufficient interest to warrant some speculation. The structure looks enough out of place to suggest that the sample studied was not *Prestonia* at all, and indeed, N,N-dimethyltryptamine was isolated from an aqueous extract of leaves the botanical origin of which appears to be in doubt. Confirmation of the presence of this alkaloid in an authentic specimen of the plant is certainly necessary.

The role of the botanist in modern plant investigation is exceedingly important. In our own laboratories we consider it mandatory to have the traditional specimen of the plant under investigation on file in a well-known herbarium. This information should be part of the publication of any definitive chemistry, for only in this way can much of the confusion in the literature ever be resolved.

Further, our own experience has shown

[1] E. Macko and R. F. Raffauf, The pharmacology of *Bleckeria coccinea* (in press).

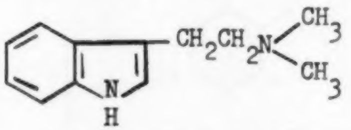
that some of the plants recorded as giving positive alkaloid tests are not positive at all. Thus the data given in Table IV below must be accepted with this reservation in mind. Other genera for which negative results have been reported may, indeed, contain alkaloids if the proper plant part is chosen for testing. This problem will be treated in greater detail elsewhere.

It is, we believe, far too early to suggest general relationships between taxonomy and alkaloid structure. But it is hoped that compilations of the existing information such as this will point to the many challenging problems in the field to which the chemist, botanist and biogeneticist alike will contribute.

TABLE I
STRUCTURAL TYPES OF ALKALOIDS

The alkaloids of the Apocynaceae can be divided into four basic structural types and one group of miscellaneous polycyclic structures containing the indole nucleus as a common feature.

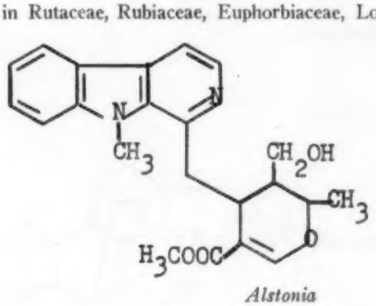
A. Simple Indoles (also found in Aceraceae, Gramineae, Leguminosae, Musaceae, Rutaceae, and certain Fungi)



Prestonia (Haemadictyon)

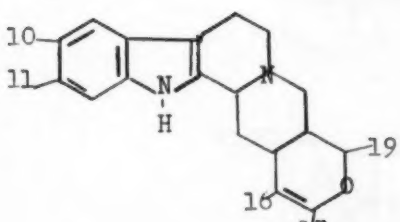
B. Carbolines (also found in Rutaceae, Rubiaceae, Euphorbiaceae, Loganiaceae)

1.

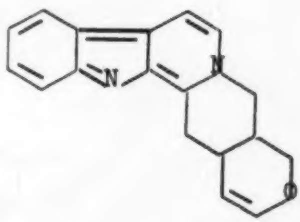


Alstonia

2.

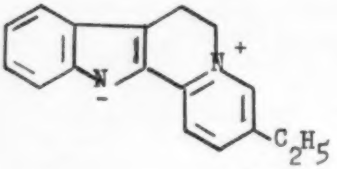


a.
Catharanthus, Rauvolfia, Vinca, Ochrosia (also in Rubiaceae)



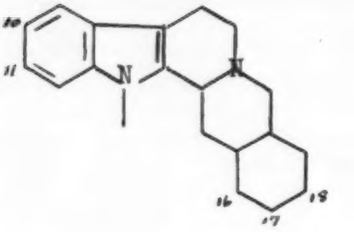
b.
Alstonia, Ochrosia, Rauvolfia, Catharanthus

3.

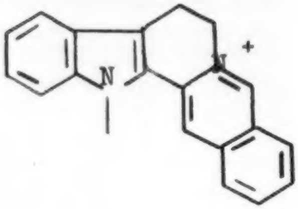


Geissospermum (also in Loganiaceae)

4.

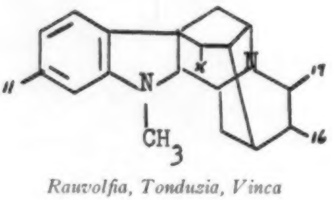


a.
Alstonia, Amsonia, Aspidosperma, Bleckeria, Catharanthus, Rauvolfia, Tonduzia, Vallesia, Vinca (also in Euphorbiaceae, Rubiaceae)



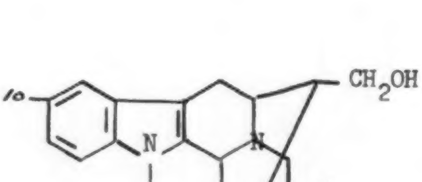
b.
Alstonia

5.



Rauvolfia, Tonduzia, Vinca

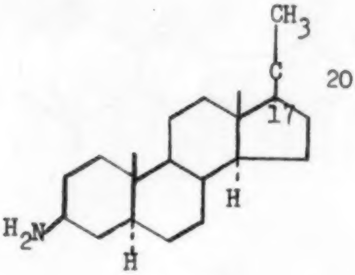
6.



Rauvolfia, Catharanthus (also in Loganiaceae)

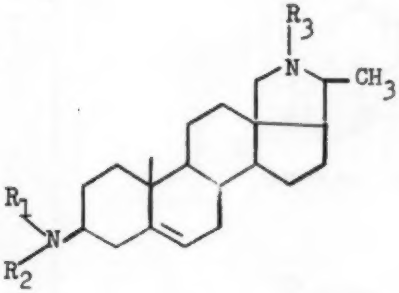
C. Steroidal Amines

1.

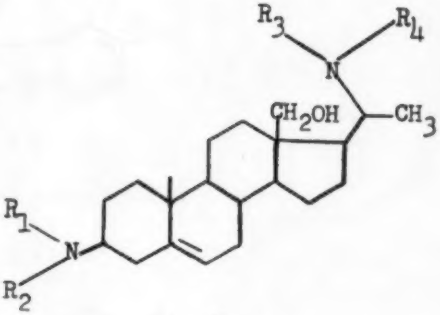


Funtumia

2.



a.
Elytropus, Holarrhena, Wrightia



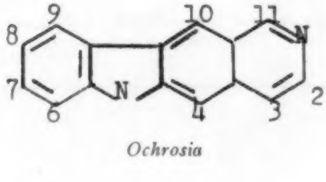
b.
Holarrhena, Wrightia

D. Isomeric Quinindolines and Quinindoles (also found in Asclepiadaceae)

1.

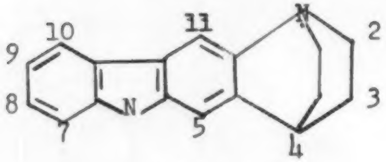
Aspidosperma

2.



Ochrosia

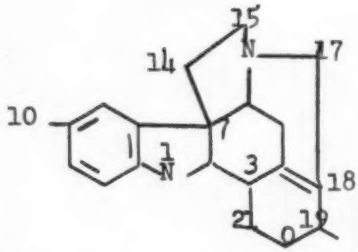
3.



Ochrosia

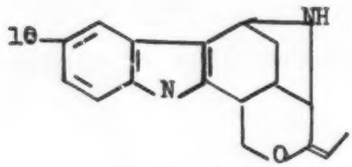
E. Miscellaneous Types

1.



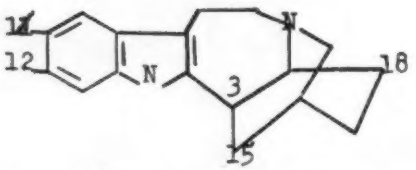
Kopsia, Picralima, Vinca, Catharanthus

2.



Picralima, Vinca

3.



Ervatamia, Rejoua, Stemmadenia, Tabernaemontana Tabernanthe, Voacanga

TABLE II

The following table lists the known alkaloids of the family, their formulas, physical properties and structures. As far as possible only the latest references have been given as a guide to earlier reports.

Alkaloid	Emp. Form.	m.p. °C	$[\alpha]_D$	t.	Solv.	Struct.	Substituents	Genera	Refs.
AJMALICINE	$C_{21}H_{24}N_2O_3$	250-252	−61		Chf.	B2a	16-MeOOC, 19-Me	Rauvolfia Catharanthus	144, 3 117, 61
AJMALIDINE	$C_{20}H_{24}N_2O_2$	241-242				B5	X = O, 17 — OH, 16 — Et	Rauvolfia	40, 25
AJMALINE	$C_{20}H_{26}N_2O_2$	264-266	72		EtOH	B5	X = OH, 17 — OH, 16 — Et	Rauvolfia Tonduzia	121, 123
AJMALININE	$C_{20}H_{26}N_2O_3$	180-181	−97		Chf.	may be 3-epi-α-yohimbine (q. v.)		Rauvolfia	82
AKUAMMENINE	$C_{20}H_{22}N_2O_4$	picrate 225						Picralima	82
AKUAMMICINE	$C_{19}H_{20}N_2O_2$	177.5	−737.5	19	EtOH Chf.			Picralima	103, 105
ψ-AKUAMMICINE	$C_{19}H_{20}N_2O_2$	187.5						Picralima	82, 105, 140
AKUAMMIDINE	$C_{21}H_{24}N_2O_3$	248.5	21	18	EtOH			Picralima	82
AKUAMMIGINE	$C_{21}H_{24}N_2O_3$	113	−42	18.5	EtOH			Picralima	104
ψ-AKUAMMIGINE	$C_{22}H_{26}N_2O_3$	165	−53.8	20		E-1	1, 19-diMe, 3-MeOOC	Picralima	104
AKUAMMILINE	$C_{22}H_{24}N_2O_4$	160	49.7	20	EtOH			Picralima	82
AKUAMMINE	$C_{22}H_{26}N_2O_4$	225	−66.7		EtOH	E-1	1, 19-diMe, 10-OH 3-MeOOC	Picralima, Vinca, Catharanthus	82, 72 59
ALSTONAMINE								Alstonia	82
ALSTONIDINE	$C_{22}H_{24}N_2O_4$	185-187				B-1		Alstonia	12, 124
ALSTONILINE	$C_{22}H_{18}N_2O_3$	356 dec.				B4b	11-MeO, 16-MeOOC	Alstonia	30
ALSTONINE	$C_{21}H_{20}N_2O_3$	>300				B2b	16-MeOOC, 19-Me, Ring C aromatic	Rauvolfia Alstonia	16, 144 108
ALSTONINE, TETRAHYDRO	$C_{21}H_{24}N_2O_3$	228-230	−86	21	Pyr.	B2a	16-MeOOC, 19-Me	Catharanthus Rauvolfia	125, 16 144, 117
AMSONIAEFOLINE	$C_{25}H_{32}N_2O_5$	220-223						Rauvolfia	36
AMSONINE		See β-Yohimbine							75
ARICINE	$C_{22}H_{26}N_2O_4$	190	−63		Pyr.	B2a	16-MeOOC, 19-Me, 10-MeO	Rauvolfia	86, 16, 144
ASPIDOSAMINE	$C_{20}H_{26}N_2O_2$	100						Aspidosperma	82

Alkaloid	Emp. Form.	m.p. °C	$[\alpha]_D$	t.	Solv.	Struct.	Substituents	Genera	Refs.
Aspidospermatine	$C_{22}H_{28}N_2O_2$	162	−73.3		EtOH			Aspidosperma	82
Aspidospermicine	$C_{17}H_{24}NO$							Aspidosperma	82
Aspidospermine	$C_{22}H_{30}N_2O_2$	208	−99	18	EtOH	N-acetyl-dihydro-indole		Aspidosperma Vallesia	88, 19, 54, 143
Canescine			See Deserpidine						
Catharanthine	$C_{21}H_{24}N_2O_2$	126-128	29.8	27	Chf.			Catharanthus	42
Chandrine	$C_{25}H_{30}N_2O_8$	230-231						Rauvolfia	16, 144
Chonemorphine	$C_{23}H_{40}N_2$	414-416(HCl)	−19.4	30				Chonemorpha	23
Cimicidine	$C_{23}H_{28}N_2O_5$	259-262 dec.	123	25	Chf.			Haplophyton	119
Conamine	$C_{22}H_{36}N_2$	97.5-101.5	−21	18	Chf.	C2a	$R_1 = R_2 = H$; $R_3 = Me$; 3-α	Holarrhena	129
Conarrhimine	$C_{21}H_{34}N_2$					C2a	$R_1 = R_2 = R_3 = H$; 3-α	Holarrhena	107
Conessidine	$C_{22}H_{34}N_2$	123-125	−49 −63.5		EtOH	C2a	$R_1 = R_3 = H$; $R_2 = Me$; Δ17	Holarrhena	107
Conessimine	$C_{23}H_{38}N_2$	100	−22		Chf.	C2a	$R_1 = R_2 = Me$; $R_3 = H$; 3-α	Holarrhena	107
Conessine	$C_{24}H_{40}N_2$	123-127	21±2	18	EtOH	C2a	$R_1 = R_2 = R_3 = Me$, 3-α	Holarrhena Wrightia	129, 7, 138
Conimine	$C_{22}H_{36}N_2$	133-135.5	27		EtOH	C2a	$R_1 = Me$; $R_2 = R_3 = H$; 3-α	Holarrhena	129
Conkurchine	$C_{21}H_{32}N_2$	152-153	43.8		EtOH	C2a	$R_1 = R_2 = R_3 = H$ Δ17	Holarrhena	107
Conkurchine, trimethyl	$C_{24}H_{38}N_2$	125-128	12	18		C2a	$R_1 = R_2 = R_3 = Me$; Δ17	Holarrhena	129
Conkurchinine	$C_{25}H_{36}N_2$	161	−4.7		EtOH			Holarrhena	107
Coronaridine	$C_{21}H_{26}N_2O_2$					E_3		Ervatamia Tabernae-montana	41
Coronarine	$C_{44}H_{56}N_4O_6$	196-198						Ervatamia Tabernae-montana	41, 135
Corynanthine	$C_{21}H_{26}N_2O_3$	218-225	−82		Pyr.	B4a	16-MeOOC, 17-OH	Rauvolfia	16, 144
Deserpidine	$C_{32}H_{38}N_2O_8$	232-234	−138		Chf.	B4a	16-MeOOC, 17-OMe, 18-OBz $(OMe)_3$	Rauvolfia Tonduzia	16, 144 121, 18, 92
Dichotamine	$C_{21\text{-}22}H_{24\text{-}26}N_2O_4$	254-257	−105					Vallesia	54

DITAMINE	$C_{16}H_{19}NO_2$					may not be a definite product		Alstonia	82
ECHITAMIDINE	$C_{20}H_{26}N_2O_3$	135	−515	16	EtOH			Alstonia	82
ECHITAMINE	$C_{22}H_{28}N_2O_4$	286 (HCl)	−57.9	30	H_2O			Alstonia	82
ECHITENINE	$C_{20}H_{27}NO_4$					may not be a definite product		Alstonia	82
ELLIPTICINE	$C_{17}H_{14}N_2$	311-315 dec.				D2	2,3-diMe	Ochrosia	39
ELLIPTICINE, METHOXY	$C_{18}H_{16}N_2O$	280-285				D2	2,3-diMe, -OMe	Ochrosia	39
ELLIPTINE		See iso-Reserpiline							
ELLIPTININE	$C_{20}H_{24}N_2O_2$	231-233	−255	24		D3	no Δ^{11}, 2-OH, 3-Et, 8-OMe	Ochrosia	39
FLAVOPEREIRINE	$C_{17}H_{14}N_2$	233-235	±0			B3		Geissospermum	97, 70
FUNTUMIDINE	$C_{21}H_{37}NO$	182	10		Chf.	C −1	20-OH	Funtumia	69
FUNTUMINE	$C_{21}H_{35}NO$	123	95		Chf.	C −1	20-O	Funtumia	69
GABONINE	$C_{21}H_{28}N_2O_4$	223-226	65	24	Chf.			Tabernanthe	24
GEISSOSPERMINE	$C_{40}H_{48}N_4O_3$	160 (H_2O)	−93.4		EtOH			Geissospermum	71, 8
GEISSOSCHIZOLINE	$C_{19}H_{26}N_2O$	84-87	32	25	EtOH			Geissospermum	97, 71
GUATAMBUINE	$C_{18}H_{20}N_2$	251 dec.	106	25	Pyr.			Aspidosperma	112, 33
HAPLOPHYTINE	$C_{27}H_{31}N_3O_5$	288-292	109	25	Chf.			Haplophyton	119
HASLERINE		237						Aspidosperma	82
HETEROPHYLLINE		See Aricine							
HOLAFRINE	$C_{29}H_{46}N_2O_2$	116-117	19.1		Chf.	C2a	$R_1 = R_2 = Me$, $R_3 = H$, 12-Me_2C = CH-CH_2COO	Holarrhena	130, 106
HOLARRHENINE	$C_{24}H_{36}N_2O$	197-198	−7.1		Chf.	C2a	$R_1 = R_2 = R_3$ = Me, 12-OH	Holarrhena Elytropus	132, 107
HOLARHESSIMINE	$C_{22}H_{36}N_2O$	160-164	−30		Chf.			Holarrhena	107
HOLARRHETINE	$C_{30}H_{48}N_2O_2$	74-75	−4.6		EtOH	C2a	$R_1 = R_2 = R_3$ = Me, 12-Me_2C = $CHCH_2COO$-	Holarrhena	130, 106
HOLARRHIDINE	$C_{21}H_{36}N_2O$	180-181	−23	20		C2b	$R_1 = R_2 = R_3 = R_4 = H$, 3α	Holarrhena	80
HOLARRHIMINE	$C_{21}H_{36}N_2O$	185-186	−11	20		C2b	$R_1 = R_2 = R_3 = R_4 = H$, 3β	Holarrhena Elytropus	130, 132 80
HOLARRHIMINE, 3-N-METHYL	$C_{22}H_{38}N_2O$	>360 (HCl)	−28		MeOH	C2b	R_1 = Me, $R_2 = R_3 = R_4 = H$, 3β	Holarrhena	130

Alkaloid	Emp. Form.	m.p. °C	$[\alpha]_D$	t.	Solv.	Struct.	Substituents	Genera	Refs.
Holarrhimine, 20-N-Methyl	$C_{22}H_{38}N_2O$	163-164	−19		Chf.	C2b	$R_1=R_2=R_3=H$, $R_4=Me$, 3β	Holarrhena	130
Holarrhimine, tetramethyl	$C_{25}H_{44}N_2O$	227-229 233-235	−35±2		Chf.	C2b	$R_1=R_2=R_3=R_4=Me$, 3β	Holarrhena	130
Holarrhine	$C_{20}H_{38}N_2O_3$	240	−17		MeOH			Holarrhena	107
Hypoquebrachine	$C_{21}H_{26}N_2O_2$	80						Aspidosperma	82
Ibogaine	$C_{20}H_{26}N_2O$	151-152				E3	11-OMe, 18-Et	Tabernanthe	43, 127
Ibogamine	$C_{19}H_{24}N_2$	163-164	−60	25		E3	18-Et	Tabernanthe Tabernae-montana Ervatamia Stemmadenia	134, 41, 127, 24
Iboluteine	$C_{20}H_{26}N_2O_2$	142	−114	19	Chf.		5-methoxyindole-3-one	Tabernanthe	45, 46, 5
Iboluteine, desmethoxy	$C_{19}H_{24}N_2O$	141						Tabernanthe	24
Iboxygaine	$C_{20}H_{26}N_2O_2$	234	−5		Chf.	E3	11 = MeO, 18 − CHOH-Me	Tabernanthe	44
Iso-Ajmaline	$C_{20}H_{26}N_2O_2$	264-266	72		EtOH			Rauvolfia	16
Iso-Conessimine	$C_{23}H_{38}N_2$	92	30		EtOH	C2a	$R_1=R_3=Me$, $R_2=H$, 3α	Holarrhena	107
Iso-Rauhimbine	See 3-epi-α-Yohimbine								
Iso-Raunescine	$C_{31}H_{36}N_2O_8$	241-242	−70		Chf.	B4a	18-OH, 16-MeOOC, 17-OBz $(OMe)_3$	Rauvolfia	16, 144, 84
Iso-Rauwolfine	See Iso-Ajmaline								
Iso-Reserpiline	$C_{23}H_{28}N_2O_5$	211-213	−82		Pyr.	B2a	10,11-diMeO, 16-MeOOC 19-Me	Rauvolfia Ochrosia	16, 144 39, 86
Iso-Reserpinine	$C_{22}H_{26}N_2O_4$	225-226	−5		Pyr.	B2a	11-MeO, 16-MeOOC, 19-Me	Rauvolfia	16, 144
Iso-vincamine	$C_{21}H_{26}N_2O_3$	218-219	28		Pyr.			Vinca	91
Iso-Voacangine	$C_{22}H_{28}N_2O_3$	156-157	−52	22		E3	3-COOMe, 12-MeO 18-C_2H_5	Stemmadenia	134
Kamassine	See Quebrachamine							Gonioma	50, 34
Kimvuline	$C_{20}H_{26}N_2O_2$	231-232.5	3.7		Chf.			Tabernanthe	24
Kisantine	$C_{21}H_{28}N_2O_3$	236-238	−15	26	Chf.			Tabernanthe	24

Kopsamine	$C_{24}H_{28}N_2O_7$	203-204	−46.4	23	Chf.			Kopsia	11
Kopsaporine	$C_{23}H_{26}N_2O_6$	234 dec.	48					Kopsia	74
Kopsiflorine	$C_{28}H_{28}N_2O_5$	144-145	−66.9	23	Chf.			Kopsia	22
Kopsilongine	$C_{24}H_{30}N_2O_6$	206-208	−18.2	23	Chf.			Kopsia	22
Kopsine	$C_{22}H_{26}N_2O_4$	218 dec.				E-1	3-MeOOC, 0-heterocyclic ring 7-membered, 21-OH, 19-H	Kopsia Picralima	11
Kopsingarine	$C_{23}H_{28\text{-}30}N_2O_7$	230 dec.	14					Kopsia	74
Kopsingine	$C_{24}H_{28}N_2O_7$	270-274 dec.	75					Kopsia	74
Kopsinine	$C_{21}H_{26}N_2O_2$	104-105	−76.9	23	Chf.			Kopsia	22
Kurchamine	$C_{22}H_{36}N_2$	115-117	16±2	15	Chf.	C2a	probably no Δ^5, $\Delta 17$	Holarrhena	130
Kurchicine	$C_{20}H_{36}N_2O$	175	−11.4		Chf.		probably impure holarrhimine	Holarrhena	80
Kurchine	$C_{23}H_{38}N_2$	75	6.4		EtOH	C2a	Δ^{17}, probably no Δ^5	Holarrhena	130
Lanceine	$C_{20}H_{26}N_2O_3$ } $C_{24}H_{30}N_2O_4$ }	198						Catharanthus	65
Lettocine	$C_{17}H_{25}NO_2$	350-352						Holarrhena	107
Leurosine		200-203 (6 H_2O)	59.8	25	Chf.			Catharanthus	88
Lochnericine	$C_{21}H_{24}N_2O_3$	190-193 dec.	−43.2	27	Chf.			Catharanthus	42, 85
Lochnerine	$C_{20\text{-}21}H_{26\text{-}28}N_2O_2$	200-201	50	21	EtOH	B6	10-MeO	Catharanthus	2, 94, 61, 83
Macoubeine	$C_{22}H_{26}N_2O_2$							Macoubea	50
Macralstonidine	$C_{41}H_{50}N_4O_3$	270	174.5					Alstonia	82
Macralstonine	$C_{44}H_{54}N_4O_5$	293 dec.	27.5					Alstonia	82, 129
Macrophylline	$C_{44}H_{54}N_4O_5$	267-268 dec.						Alstonia	82
Mauiensine	$C_{20}H_{26}N_2O$	240-242	184		MeOH			Rauvolfia	40
Minorine	$C_{22}H_{28}N_2O_3$	224-225						Vinca	145
Nerifoline		293-294						Alstonia	17
Ochrelline		266 dec.						Ochrosia	20
Olivacine	$C_{17}H_{14}N_2$	318-324	0	25	Pyr.	D-1		Aspidosperma	113
Palosine	$C_{23}H_{32}N_2O_2$	149-152	−85.9	24	Chf.	dihydro-indole		Aspidosperma	115
Papuanine	$C_{22}H_{26}N_2O_4$	293 dec.						Voacanga	20
Paytamine	$C_{21}H_{24}N_2O$							Aspidosperma	82
Paytine	$C_{21}H_{24}N_2O$	156	−149.5		EtOH			Aspidosperma	82
Perakenine		236						Rauvolfia	16, 144
Pereirine	$C_{19}H_{24}N_2O$	124	137.5		EtOH			Geissospermum	8
Perivincine	$C_{23}H_{26}N_2O_4$	201-202 dec.						Vinca	109
Perivine		180-181						Catharanthus	125

Alkaloid	Emp. Form.	m.p. °C	$[\alpha]_D$	t.	Solv.	Struct.	Substituents	Genera	Refs.
Pubescine	$C_{20}H_{26}N_2O_4$	227-228	−134.2		EtOH			Vinca	90
Quebrachamine	$C_{19}H_{26}N_2$	147-149	−111 +111	25 25		indole		Aspidosperma Stemmadenia	89, 142, 134
Quebrachine	See Yohimbine								
Quirandine		218						Aspidosperma	82
Raubasine	See Ajmalicine								
Raubasinine	See Reserpinine								
Raugustine	$C_{32}H_{38}N_2O_9$ (H_2O)	262-263 (NO_3)	−50	24	Chf.	B4a	11-OMe, 17-$(MeO)_3$Bz 18 OH	Rauvolfia	84
Rauhimbine	See Corynanthine								
Raujemidine	$C_{33}H_{40}N_2O_9$							Rauvolfia	16, 144
Raumitorine	$C_{22}H_{26}N_2O_4$	138	60		Chf.	B2a	10-MeO, 16-MeOOC, 19-Me	Rauvolfia	48, 86
Raunescine	$C_{31}H_{36}N_2O_8$	160-170	−74		Chf.	B4a	16-MeOOC, 17-OH, 18-OBz $(OMe)_3$	Rauvolfia	16, 144, 84
Raunormine	See Deserpidine								
Raupine	See Sarpagine								
Rauvomitine	$C_{30}H_{34}N_2O_5$	115-117	−173.4		Chf.	B5	X=OBz $(OMe)_3$, 16-Et	Rauvolfia	25, 47
Rauwolfine	See Ajmaline								
Rauwolfinine	$C_{18}H_{22}N_2O_2$	235-236	−34.7			B5	bridge across rings B-C is -O-CHOH-CH_2-	Rauvolfia	13
Rauwolscine	See α-Yohimbine								
Recanescine	See Deserpidine								
Renoxydine	$C_{33}H_{40}N_2O_{10}$	238-241 dec.	−100	25	Chf.	B4a	reserpine N-oxide (q.v.)	Rauvolfia	131
Rescinnamine	$C_{35}H_{42}N_2O_9$	226	−98		Chf.	B4a	11-MeO 16-MeOOC, 17-OMe, 18-$(MeO)_3$-cinnamoyl-	Rauvolfia Tonduzia	121, 16, 144

RESERPILINE	$C_{23}H_{28}N_2O_5$	amorph.	−14		Pyr.	B2a	10,11-diMeO, 16-MeOOC, 19-Me	Rauvolfia	48, 79
RESERPINE	$C_{33}H_{40}N_2O_9$	277-278	−117		Chf.	B4a	11-MeO, 16-MeOOC, 17-OMe, 18-OBz$(OMe)_3$	Rauvolfia Catharanthus Alstonia Bleckeria Tonduzia Vallesia	16, 144, 54, 121, 118, 21, 6
ψ-RESERPINE	$C_{32}H_{38}N_2O_9$	257-258	−65	24	Chf.	B4a	17-desmethyl reserpine	Rauvolfia	77
RESERPININE	$C_{22}H_{26}N_2O_4$	238-239	−121		Chf.	B2a	11-OMe, 16-MeOOC, 19-Me	Rauvolfia Vinca	16, 144, 3
SANDWICENSINE	$C_{19}H_{22}N_2O$	260-262	56		MeOH			Rauvolfia	40
SANDWICINE	$C_{20}H_{26}N_2O_2$	amorph.	180		Chf.	B5	X = OH, 17-OH, 16-Et	Rauvolfia	40
SARPAGINE	$C_{19}H_{22}N_2O_2$	340-344	52		Pyr.	B6	10-OH	Rauvolfia	94
SEMPERFLORINE	$C_{21}H_{26}N_2$	295						Rauvolfia	16, 144
SEREDINE	$C_{23}H_{30}N_2O_5$	291	−1		Chf.	B4a	16-MeOOC, 17-OH 10,11-diMeO	Rauvolfia	95
SERPENTINE	$C_{21}H_{20}N_2O_3$	157-159	292		Chf.	B2b	ring B aromatic, 16-MeOOC, 19-Me	Rauvolfia Catharanthus	117, 16, 144
SERPENTINE, TETRAHYDRO	See Ajmalicine								
SERPENTININE	$C_{21}H_{22}N_2O_3$	263-265	52		MeOH			Rauvolfia	16, 144
SERPINE	Mixture of rauwolscine and yohimbine								51, see also 35, 15
SERPININE	May be tetraphyllicine (q.v.)								
SPEGAZZININE	$C_{21\text{-}22}H_{28\text{-}30}N_2O_3$	104.5-106	175.6		Chf.	acetylated dihydro-indole		Aspidosperma	89
STEMMADENINE		199-200 dec.	324	25	Pyr.			Stemmadenia	134
TABERNAEMONTANINE	$C_{20}H_{26}N_2O_3$	217-218 208-210						Tabernae-montana Ervatamia	41, 135
TABERNANTHINE	$C_{20}H_{26}N_2O$	211-212	−35	25		E3	12-OMe, 18-Et	Tabernanthe Stemmadenia	127, 134, 24, 4
TABERSONINE	$C_{20}H_{24}N_2O_2$	196 (HCl)	−310		MeOH			Amsonia	68
TETRAPHYLLICINE	$C_{20}H_{24}N_2O$	320-322	21		Pyr.	B5	X = OH, 16-C_2H_4	Rauvolfia Vinca	16, 144, 25, 60

Alkaloid	Emp. Form.	m.p. °C	$[\alpha]_D$	t.	Solv.	Struct.	Substituents	Genera	Refs.
Tetraphylline	$C_{22}H_{26}N_2O_4$	220-223	−73		Chf.	B2a	1 -MeOOC, 11-MeO	Rauvolfia	26, 27
Tryptamine, Dimethyl	$C_{12}H_{16}N_2$					A		Haemadictyon (Prestonia)	52
Uleine	$C_{18}H_{22}N_2$	76-118	18.5		Chf.				
			16	23	Chf.			Aspidosperma	114, 113
Vallesine	$C_{21}H_{28}N_2O_2$	154-156	−91	24	EtOH	desacetyl formyl aspido-spermine		Vallesia	54
Vellosine	$C_{23}H_{28}N_2O_4$	189	23	23	Chf.			Geissospermum	97, 70
Villalstonine	$C_{40}H_{50}N_4O_4$	260	56.3		H_2O			Alstonia	16, 144
Vincaine	See δ-Yohimbine								
Vincaleucoblastine								Catharanthus	87
Vincamajine	$C_{22}H_{26}N_2O_3$	225	−55		H_2O			Vinca Tonduzia Rauvolfia Picralima	62, 121, 64
Vincamajoreine	$C_{21}H_{26\text{-}28}N_2O_2$	271				5-OMe di-hydroindole		Vinca	59
Vincamajoridine	See Akuammine								
Vincamedine	$C_{24}H_{26\text{-}28}N_2O_4$	185	−66		Chf.			Vinca	67, 64
Vincamine	$C_{21}H_{26}N_2O_3$	231-232	39		Pyr.			Vinca	111, 63
Vincaminorine	$C_{22}H_{30}N_2O_2$	130-131	46	21	EtOH			Vinca	128
Vincanidine	$C_{20}H_{24}N_2O_3$	250-280 dec.						Vinca	145
Vincanine	$C_{19}H_{22}N_2O$	187.5-188	−99.2		MeOH			Vinca	145
Vinceine	See δ-Yohimbine								
Vindoline	$C_{25}H_{32}N_2O_6$	150-152 (½ H_2O)						Catharanthus	42, 73
Vindolinine	$C_{21}H_{24\text{-}26}N_2O_2$	210-212 dec. (2 HCl)	−8	27	H_2O			Catharanthus	42
Vinine	$C_{19}H_{26}N_2O_4$	211-213	−70		EtOH			Vinca	90
Virosine		257-262 dec.						Catharanthus	125
Voacafricine	$C_{22}H_{24\text{-}26}N_2O_4$	196-198						Voacanga	96
Voacafrine	$C_{22}H_{26}N_2O_4$	135-137 dec.	−107	25	Chf.			Voacanga	96
Voacaline	$C_{41}H_{50}N_4O_6$	280-285	−47.5		Chf.			Voacanga	78
Voacamidine	$C_{45}H_{56}N_4O_6$	128-130 dec.	−174.5	24	Chf.			Voacanga	100

Voacamine	$C_{45}H_{56}N_4O_6$	222-223	−52	20	Chf.			Voacanga Stemmadenia Ervatamia Tabernae- montana	58, 134, 57
Voacaminine	$C_{45}H_{56}N_4O_6$	242	−48	20	Chf.			Voacanga	58
Voacangarine	$C_{22}H_{28}N_2O_4$	92-94/ 166-167	−29	20	Chf.	E3	11 − MeO, 18 − CH_2-CH_2OH 3 − AcO	Voacanga	122
Voacangine	$C_{22}H_{28}N_2O_3$	137-138	−28 −42 −34	25 20 26	Chf.	E3	11-MeO, 18-Et, 3-COOMe	Voacanga Ervatamia Tabernae- montana Stemmadenia Rejoua Tabernanthe	58, 20, 41, 116, 24, 134, 4, 57
Voacorine	$C_{45\text{-}46}H_{54\text{-}56}N_4O_7$	273	−35	25	Chf.			Voacanga	96
Voacristine	$C_{23}H_{30}N_2O_4$	112-114	−24.5		Chf.			Voacanga	100
	$C_{45}H_{58}N_4O_8$								
Voacryptine	$C_{22}H_{26}N_2O_4$	175-176	24.7	22	Chf.			Voacanga	101
Vobasine	$C_{21}H_{24}NO_3$	111-113	−158.5	23	Chf.			Voacanga	101
Vobtusine	$C_{45}H_{54}N_4O_8$	286	−321		Chf.			Voacanga	58, 116, 57
Vomalidine	$C_{21}H_{26}N_2O_3$	242-243	210	20	Pyr.	B5	17 − OH, X = O, 11-MeO, 16-Et	Rauvolfia	53
Yohimbine	$C_{21}H_{26}N_2O_3$	233-234	105.1	19	Pyr.	B4a	16-MeOOC, 17-OH	Rauvolfia Aspidosperma	82, 16, 144, 66
α-Yohimbine	$C_{21}H_{26}N_2O_3$	239-241	−15		Pyr.	B4a	16-MeOOC, 17-OH	Rauvolfia	16, 144
3-Epi-α-Yohimbine	$C_{21}H_{26}N_2O_3$	225-228	−104		Pyr.	B4a	16-MeOOC, 17-OH	Rauvolfia	16, 144
β-Yohimbine	$C_{21}H_{26}N_2O_3$	246-249	−48		Pyr.	B4a	16-MeOOC, 17-OH	Rauvolfia Amsonia	16, 144, 75
δ-Yohimbine	See Ajmalicine								
ψ-Yohimbine	$C_{21}H_{26}N_2O_3$	265-278	27		Pyr.	B4a	16-MeOOC, 17-OH	Rauvolfia Vinca	16, 144

TABLE III

MISCELLANEOUS UNNAMED BASES

	Genus	Description	Reference
1.	Alstonia	Base V, m.p. 273 dec.; $[\alpha]_D$ 54.6	82
2.	—	Base M, m.p. 257 (SO_4); $[\alpha]_D$ −71.9 (H_2O)	82
3.	Amsonia	Alkaloid, m.p. 230-31 dec.; $[\alpha]_D^{31}$ 13.2	55
4.	—	Alkaloid, $C_{19}H_{24}N_2O_3$, m.p. 263-265 dec.; indole	55
5.	Aspidosperma	Base, m.p. 149-150	82
6.		Base, m.p. 176-177	82
7.		Base, m.p. 201-201.5; $[\alpha]_D^{20}$ 92.7	1
8.		u-alkaloid B, $C_{18}H_{20}N_2$; m.p. 215-218 dec. $[\alpha]_D$ 0; carbazole spectrum	39, 112
9.		u-alkaloid C, see Guatambuine in Table I	112
10.		u-alkaloid D, $C_{17}H_{16}N_2$, m.p. 308-312 dec.; $[\alpha]_D$ 0 (Pyr.)	112
11.	Bleckeria	Yellow base identical with one found in Ochrosia	20
12.	Geissospermum	Alkaloid D_1, m.p. 237-238	97
13.		Alkaloid D_3, $C_{38}H_{46}N_4O$, m.p. 133-135; $[\alpha]_D^{25}$ 74	97
14.		Alkaloid E_1, $C_{20}H_{24}N_2$; m.p. 163-165; $[\alpha]_D^{24}$ −51 (EtOH)	97
15.	Ochrosia	Alkaloid, $C_{18}H_{16}N_2O$, m.p. 282-284; $[\alpha]_D$ ±0 may be methoxyellipticine	14
16.		Alkaloid, m.p. 215 [HI]; $[\alpha]$ 27 at 5890	39
		Yellow base	20
17.	Rauvolfia	Alkaloid, $C_{21}H_{22}N_2O_3$, m.p. 207; $[\alpha]_D^{20}$ −72 (Pyr.)	53
18.		Alkaloid, $C_{14}H_{16}N_2$, m.p. 190-192; $[\alpha]_D$ −132 (Pyr.)	16
19.	Tabernanthe	$C_{19}H_{24}N_2O$, m.p. 100/168-172; $[\alpha]_D^{25}$ 82.5 (95% EtOH) may be an artifact; hydroxyindolenine derivative of ibogamine	24
20.		$C_{20}H_{26}N_2O_2$, m.p. 123-124; $[\alpha]_D$ 74 (EtOH) hydroxyindolenine derivative of ibogaine; may be artifact	24
21.		Iboquine, $C_{20}H_{24}N_2O_4$, m.p. 268-271 or 284; may be artifact	24
22.	Vinca	Alkaloid, $C_{20}H_{26}N_2O_2$, m.p. >360; $[\alpha]_D$ 55	63
23.		Alkaloid, m.p. 242	6
24.		Alkaloid	133

TABLE IV

OTHER ALKALOID-CONTAINING GENERA

The following genera have been reported to contain alkaloids not characterized further:
Acokanthera (138), *Allamanda* (29) (102), *Alyxia* (110) (136) (137), *Anacampta* (102) (118), *Beaumontia* (29), *Calpicarpum* (82), *Carissa* (136), *Carpodinus* (10), *Chilocarpus* (29) (137), *Conopharyngia* (118), *Cryptostegia* (136), *Cyrtosiphonia* (138), *Dyera* (29), *Forsteronia* (76), *Gabunia* (118) (81), *Gonioma* (50), *Hunteria* (98) (118), *Kickxia* (138), *Lactaria* (76), *Leuconotis* (29) (138), *Malouetia* (118)**, *Melodinus* (136), *Nerium* (118) (76), *Odontadenia* (10), *Ophioxylon* (138), *Pachypodium* (56), *Parsonsia* (136), *Peschiera* (118), *Pleiocarpa* (29) (99), *Pleioceras* (10), *Plumeria* (29), *Pseudochrosia* (138), *Pteralyxia* (110), *Rhabdadenia* (10), *Rhazya* (10), *Rhyncodia* (138), *Roupellia* (29), *Stenosolen* (102), *Tanghinia* (76), *Thevetia* (29), *Trachelospermum* (118), *Urechites* (82), *Wallichiana* (76), *Willughbeia* (29). Trigonelline has been found in *Strophanthus* (138) and carpaine in *Cerbera* (120).

**See Bisset re: guachamacine

Conclusions

Of the 150-200 genera of the Apocynaceae about 60 have been reported to contain a total of some 200 alkaloids. Very few of these have found extensive use in modern medicine e.g. the alkaloids of *Rauvolfia, Holarrhena, Tabernanthe, Voacanga.* This is due in part to the lack of pharmacological data on individual compounds, and often is the result of the extremely low yields of minor plant constituents which preclude such studies. On the other hand, the seemingly minor variations in structure between members of a group of closely related alkaloids are often the differences between useful drugs and laboratory curiosities.

The medicinal and economic importance of the genus *Rauvolfia* has led to extensive chemical studies of the family as a whole. To the chemist any relationships between

alkaloid structure and taxonomy may be of valuable assistance in his examination of new plants. To the botanist these relationships may suggest changes in classification within the family particularly in those cases where no clear-cut decision can be made on purely morphological grounds. Our knowledge of the Apocynaceae is far from complete, but there do appear some trends which may help direct future research in this challenging field.

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The Search for New Industrial Crops

Advances in technological development have produced an ever-increasing pressure for new and different raw materials to keep pace with changing industrial needs. Many new and useful properties of plants may be discovered through the modern chemistry and technology of utilization research. The U. S. Department of Agriculture's search for new industrial crops is a coordinated botanical and utilization research program.

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The oldest geologic record of man apparently is early in the Pleistocene epoch (3). For roughly a million years, then, man has lived with virtually the same species of plants which comprise the world's flora today. Throughout this time he has experimented with the plants around him. Perhaps by trial and error, but also by observation and deduction, motivated by hunger, cold, pain, fear and superstition, man has rather thoroughly screened the earth's flora for materials which could serve his ever-increasing needs.

Some maintain that man has so thoroughly sampled the plants in his environment that there is little likelihood that useful new sources, at least of major plant constituents, will be found. In support of this contention they cite the fact that in historic time not a single wild species has been brought under cultivation to supply a raw material which had not previously been exploited from the species in the wild. Man has brought many crops into cultivation that had previously been exploited from natural stands and he has discovered and developed useful new constituents in old crops. However, he has so far not combined the discovery of a new useful constituent with successful domestication of a new source species.

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There can be little doubt that man's search for useful products in the plant kingdom has been a thorough one. The cryptic constituents which he has discovered in plants and converted into useful products often through complicated processing schemes attest to the thoroughness of his screening. The principal caffeine beverages provide a good example. There are nine of them, derived from as many species, distributed among six plant families, and growing in widely separated regions of the world. Each of the ancient centers of agriculture and civilization had its own beverage plant. The obscure constituent common to all of them is the alkaloid caffeine. It is believed that this hidden substance was independently discovered at least *nine* times by prehistoric man.

Another example of man's ingenuity, or luck, in discovering the hidden attributes of plant materials is provided by the alcoholic beverages. It is not difficult to picture a situation leading to the discovery of fermentation of naturally occurring sugars by wild yeasts but imagining the discovery of processes for converting starch to sugar requires far more supposition. We can only wonder how ancient man discovered that saliva could be used to convert starch into sugar, which in turn could be fermented to alcohol. Yet this process was independently discovered at least twice, once in Asia with barley or rice as the starch source, and once in the New World with maize or potatoes as the starting material.

It is equally difficult to imagine how man discovered that when starch-rich seeds of cereals are in the process of germinating they are rich in enzymes which initiate the conversion of starch to simple sugars and thus provide a good medium for alcohol-forming yeasts. Evidence strongly suggests that this phenomenon was also independently discovered at least twice in man's history, in the Near East and in the Americas.

Many more examples could be mustered to testify to the thoroughness of man's plant screening activities over the tens of thousands of years. The evidence cannot be refuted, but exception may be taken to the ultimate conclusions drawn from it. We can grant that man has, with the tools and knowledge available to him, rather completely sampled the world's plant resources. But the qualification *with the tools and knowledge available to him* is all important.

NEW APPROACHES AND OBJECTIVES IN PLANT SCREENING

The development of modern science and technology in the last hundred years has provided man with tools and knowledge to probe much deeper into the complexities of the composition of his environment than has ever been possible before. This same advance in technological development has produced an ever-increasing pressure for new and different raw materials to keep pace with changing industrial needs. Man in his plant screening activities has only begun to take advantage of the new approaches and new objectives borne of the industrial revolution. But a beginning has been made and the results already achieved give us confidence that the possibilities are excellent for finding many new useful properties of plants through the modern chemistry and technology of utilization research. Furthermore, the many recent advances in the plant sciences, both basic and applied, can provide the know-how needed to develop crop sources of usable constituents discovered by utilization research.

Results will not be quickly or easily achieved. None of our present crops, we can be reasonably sure, attained an established niche in agriculture without at least decades of directed endeavor. Many others have failed to attain crop status perhaps more because of a lack of sustained research interest than lack of economic potential in the species involved. A carefully planned program, based from the beginning on the best available information and with provisions for frequent refinements of evaluations of promising species as new information is brought to light, offers the best formula for success.

PLANT RESOURCES INVENTORIES AND DIRECTED SCREENING

It has been said that science is organization of information. According to this definition, economic botany as a science is in its infancy. Knowledge of the composition and uses of plants is widely scattered in the literature of botany, chemistry, ethnology, archaeology, and pharmacology and only piecemeal attempts have been made at systematization and collation.

Information on the needs of industry for new raw materials is lacking. Chemists, physicists and engineers of industry may often know the kinds and properties of materials which would permit the development of new products or the improvement of production and quality of existing commodities, but usually this information does not reach those in a position to advise on possible plant sources of the desired materials. Careful selection of the objectives of a program for screening new crops must be based on information on the existing opportunities and future needs for plant-derived materials by industry. Direction toward these objectives

is provided by knowledge of the resources to be found in plants. This knowledge will come, in the beginning phases of the screening program, largely from the literature. But as chemical screening progresses, new leads will be uncovered and evaluated and may suggest new directions toward the objectives.

Obviously the task of compiling and systematizing all information on compositional characteristics of plants, and the uses, if any, which have been made of these, will never be completed. It can, however, be brought to an effective degree of completeness if effort commensurate with its importance is brought to bear. By nature this is a long-term project requiring organization and continuing support. Maximum value will be derived only if the major responsibility for systematizing and correlating information is centralized.

Bibliographic research on plant resources can take any of several courses. An end-use category can be made the subject of the research irrespective of plant groups which it might involve. For example, an exhaustive search for information on vegetable tannins would cut across many taxonomic lines. The end product of such a study could be a compendium on the occurrence, nature and use of vegetable tannins. Or a particular plant group, whether family, genus, or species, could be studied from the standpoint of the resources found in its members. The genus *Crotalaria* of the legume family, for example, might be subjected to detailed study for the purpose of evaluating the potential of the genus as a source of pulp for paper, cordage fiber, forage protein, seed oils, alkaloids, flavones, and tannins. The end product of such a study as this could be an economic-botanical monograph setting forth the resources of a particular genus.

The first approach lends itself better to servicing concurrent chemical screening programs than does the latter because of the necessary objectivity of analytical work and the mutually beneficial interchange of leads developed from bibliographic research on the one hand and chemical research on the other, both directed toward a single objective. Eventually, constituent-centered screening will reach a point of diminishing return and crop and constituent development will become increasingly important. It will then be extremely useful to have information organized on a taxonomic basis, for the questions which will need answering will be of the following kind: What other constituents of possible by-product value do plants of this species possess? What are the nature and extent of variations in the source species with regard to the principal constituents? What are the apparent ecological requirements of plants of this species? Are there closely related species which might be more amenable to cultivation or which might provide valuable germ plasm for improvement breeding? At this later stage the search for useful new plant products will go deeply into a relatively few promising areas rather than shallow and broad as required in the earlier stages of screening.

A successful new crops screening program is then dependent upon close liaison between plant scientists and those engaged in utilization research. The compilation of comprehensive plant resources files and evaluation of the information they contain are best accomplished by scientists of various disciplines pooling background knowledge. This same close cooperation must continue through the action program of procuring and analyzing plant materials for useful constituents. In the plant procurement phase the botanist gives leadership, but his planning and operations are guided by objectives arrived at by consultation with the chemist. When the plant materials reach the laboratory the chemist assumes the leading role, but he

can profitably consult the botanist regarding plant histology and morphology as they concern analytical procedures and results. Evaluation of the analytical data in terms of use potential and crop potential again calls for joint consideration by the chemist and the botanist. Only in this way can the most promising leads be developed for directing the course of future screening and indicating the most promising species for follow-up in characterization, developmental, and cultural studies.

Federal Participation in Inventorying Plant Resources

The history of federal participation in plant introduction and new crops research has been lucidly presented by Hodge and Erlanson (4). Since its inception in 1898, what is now the New Crops Research Branch (formerly Section of Plant Introduction) has had as its principal functions the introduction into cultivation of new plant materials from all parts of the world and the preliminary testing of this material for potential use in the agriculture of the United States. Many valuable transplants from foreign agricultures have been added to the crop roster of the United States through the activities of this unit. An even more important contribution has been the continuous flow of plant germ plasm for the improvement breeding programs for all our established crops. This important work is continuing and has even been bolstered by additional support in recent years. Since about 1950, when the extensive screening program for plant precursors of cortisone was begun, increasing emphasis has been placed on inventories of plant resources and procurement for utilization screening. The cortisone project from the beginning was a cooperative effort of botanists of the New Crops Research Branch and chemists of the Eastern Utilization Research and Development Division and the National Institute of Arthritic and Metabolic Diseases. The first two are agencies of the Department of Agriculture and the last is a unit of the National Institutes of Health. The botanical side of this work, including an extensive bibliography, has been detailed in *Economic Botany* (1). This program has provided good examples of the accomplishments which can be made through team effort by scientists of various disciplines. It has also served to indicate especially well the need for organized information on plant resources.

As a major screening program progresses it will furnish the most pertinent leads to promising areas of investigation for the sought constituent, but in the preliminary stages planning must be based on information gleaned from the literature of several fields of science. Too often, because of the simultaneous commencement of the chemical and bibliographical work, insufficient time is available for a thorough bibliographical search for the kinds of information which will provide guidance for the planning and initial stages of a screening program.

A start has been made in the Agricultural Research Service of the U. S. Department of Agriculture toward filling the need for organized information on plant resources. Four professional botanists in the New Crops Research Branch are working essentially full-time on this problem. Each staff member has assumed responsibility for a number of end-use categories, such as gums and waxes, seed proteins and oils, drugs and medicinals, fibers, etc., and is systematically gathering, evaluating and organizing information on these subjects. In addition, through correspondence and personal contact with people in industrial fields, attempts are being made to discover existing and future opportunities and needs for plant raw materials.

Chemists in another unit of the Agricultural Research Service, the Northern Utilization Research and Development

Division, are working closely with botanists of the New Crops Research Branch in a coordinated effort to derive maximum value from literature surveys. One contribution resulting from this cooperative research appeared in a recent number of this journal (*7*). In this case the chemists conducted an extensive literature survey on seed proteins, giving special attention to amino acid composition and the total quantity of protein produced by seeds. The botanist's contribution consisted of providing crop potential ratings for the species involved, collaborating on the inferences drawn, and checking the botanical nomenclature. Similar cooperative work involving other plant constituents is in progress.

Often the chemist is in a better position to determine the needs of industry for new plant materials than is the botanist. The highly technical field of the chemistry of vegetable oils, for example, can best be probed intelligently by chemists specializing to some degree in this subject. They can talk the language of the industrial chemist. Their findings can then be translated into terms meaningful to the botanist, who in turn is in the best position to suggest likely plant sources and undertake procurement.

New Crops Screening Programs in the Department of Agriculture

The search for new industrial crops consists of far more than the compiling of plant resources inventories and chemical screening for useful plant constituents. Since the present paper deals almost exclusively with these aspects of the program it is a reflection of current activity rather than an attempt to encompass all that is involved in developing new crops. Much will be said about the crop- and product-development facets of new crops research as these activities become increasingly important in the over-all program.

In July 1956 the Department of Agriculture considerably expanded its new crops research program. In the Agricultural Research Service several special units were established to provide an integrated attack on the broad problems involved. The utilization screening research was assigned to the Northern Utilization Research and Development Division and the botanical and cultural evaluation activities were centered in the New Crops Research Branch, Crops Research Division. The following discussion deals with aspects of the work of these two units.

As stated, the careful selection of the objectives of a new crops screening program means judicious contemplation of existing opportunities and needs. The objectives require continuing re-examination and re-evaluation as more is learned about our plant resources through the literature, in the laboratory or field, and through continuing surveys of the varying needs of industry for different plant raw materials. In this era of expanding and rapidly changing needs for plant products, it would be shortsighted indeed to consider only plant constituents which can satisfy present industrial markets. New crops research, with directed screening as the starting point, must be aimed also at anticipating the needs of both industry and agriculture for new plant materials. In Fig. 1 are shown existing trends in consumption of some selected major commodities.

New pulp crops. It is apparent from Fig. 1 that an expanding market exists in supplying fibrous raw materials required in the large paper and paper-products industry. Something over 32 million tons of paper of all kinds is now consumed annually in the United States and the rate of increasing consumption is exceeding that of population growth. In the past wood supplied practically all the raw materials needed by this giant industry. It is questionable whether future needs can al-

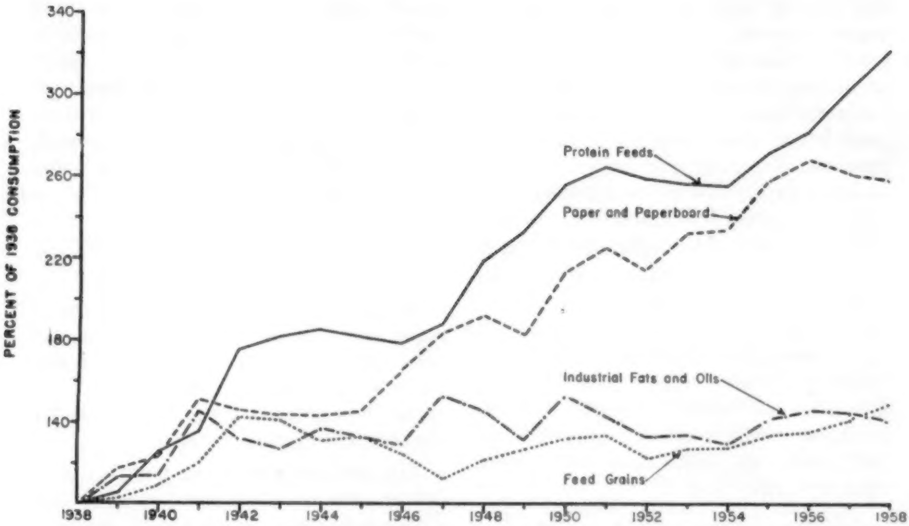


Fig. 1. Trends in consumption of some selected major commodities.

ways be met in this way. Alternative economic sources of fibrous material are not now apparent. However, existing information indicates that the chances are good for finding and developing one or more annual crops which are technologically suitable for processing into various paper products or dissolving pulps and which have sufficient yield per acre to place them on a favorable competitive basis with presently established crops. Screening research is underway toward these objectives.

New protein sources. The trend in consumption of protein feeds indicates another promising area for new crops research. Both total protein feed consumed and the amount utilized per animal unit greatly increased in the last 20 years, as shown in Fig. 1. This trend reflects the emphasis placed on better animal nutrition. Not only is there a strong trend toward higher protein rations, but nutritionally better proteins are in demand because our common protein feedstuffs are deficient in several essential amino acids.

Industrial use of proteins, while small percentagewise compared with feed use, amounts to more than 100 million pounds annually. Present uses are numerous and diverse, suggesting that the potentialities for new industrial uses of protein are good. Each 25-percent increase in industrial utilization of protein would provide a market for almost a million bushels of a seed crop which contained 50-percent protein. The current screening program on new seed and forage sources for more and better protein has already produced encouraging leads.

New vegetable oils for industry. On the basis of the trend shown in Fig. 1, there would seem to be little justification for a search for new industrial oils. The graph, however, is based on our presently utilized oils with their rather limited range of applicability. Failure of vegetable oils to maintain their competitive position as raw materials of industry is due at least in part to certain deficiencies in their properties. Industrial or non-food uses of fatty oils remained at a little over 3 bil-

lion pounds annually during the last 10 years, whereas the traditional markets for these materials in protective coatings, soaps plus detergents, and various other industrial uses greatly expanded. The need is for economical plant sources of *unusual oils,* new and superior types, which can enter new industrial markets or recapture portions of markets lost to synthetic materials of non-agricultural origin.

Screening investigations for superior sources of seed proteins and for unusual seed oils go hand-in-hand. Such work is a major activity in the Department of Agriculture's new crops program, and screening has already revealed oilseeds having a greater combined amount of oil and protein, the most valued constituents, than soybeans.

Collateral objectives. There are many other worth-while objectives for new crop screening programs. Some of these, as distribution of personnel and support permit, will become the subject of research projects. Meanwhile, maximum use is being made of plant samples for current projects in that these are examined for secondary or minor constituents as well as for major ones which constitute the primary objectives. Seeds with minimum amounts of oil and protein and lacking starch are likely sources for non-starch carbohydrate gums. Unusually high ash in seed analyses invites examination for minerals of economic importance. Alkaloids, presently of much interest to many lines of medical research, are frequently in highest concentrations in seeds and their presence or absence is easily determined. Hard waxes, for which we are almost entirely dependent on foreign sources, are usually found on the epidermis of leaves and stems. Samples for pulping evaluation can be readily checked for wax content.

Other minor constituents or trace components such as growth factors, hemagglutinins, anti-tumoral compounds, allergenic substances, etc., may be very important in their own right or may have an important bearing on feed or food usage of a plant or its major constituents. Information on constituents in any of these categories frequently comes as a byproduct of screening activities having other primary objectives.

PROCUREMENT OF PLANT MATERIALS FOR SCREENING

This activity within the Department of Agriculture is the responsibility of the New Crops Research Branch. Close liaison is maintained with chemists of Utilization Research who are responsible for the chemical evaluation work.

The ultimate goal of the program is, of course, new crops for the United States. This qualification immediately restricts, somewhat, our range of procurement activities. Strictly tropical species, adaptable in this country only to southern Florida, are largely ignored. Sometimes, however, even these are sought because of special interest of one kind or another. For example, an unusual seed oil may be of interest because from research on it may come processes for chemically altering our common vegetable oils to give them the desired properties of the unusual oil. Tropical members of families with temperate-zone representatives may provide leads worthy of further investigation with adaptable species. Largely, though, we are concerned with plants of cold-temperate to sub-tropical distribution.

The four principal means to obtain analytical samples are: (1) collection from the wild, (2) purchase from commercial seed houses, (3) collection from plantings maintained at botanic gardens and Federal Plant Introduction Stations, and (4) special increase plantings of materials acquired in too small amounts from (1), (2), or (3). Collections from the wild represent by far the largest category of materials. Increase plantings become

more important as preliminary screening indicates promising areas for follow-up research with its requirements for larger amounts of analytical material.

In the early months of the program there was considerable pressure to start as quickly as possible a flow of materials to the laboratory. Field collecting was not immediately practicable. The program relied heavily on seed houses specializing in ornamentals and specialty plants from which ¼ to 2 pounds of seed could be obtained readily. Many annual species, grown only as ornamentals in this country, represent a large number of plant families; also each is adaptable to conditions in at least some part of the United States. These annuals are good prospects for materials in a new crops screening program. Subsequent results have been extremely gratifying. This group has been the most lucrative source of promising new seed oils.

We took full advantage of the array of plant materials growing at the four Federal Plant Introduction Stations (Glenn Dale, Md., Savannah, Ga., Miami, Fla., and Chico, Calif.). Both seed samples for oil and protein analyses and herbage samples for pulping studies came from these facilities. Botanic gardens in many countries, though not supplying actual analytical samples, provided small amounts of seed of many species for increase under cultivation. Most such material could have been obtained from wild stands only at excessive costs.

Now that the program has been in operation for 2 years and over 2,500 samples have been provided the chemists, there is more and more dependence upon collection from the wild to meet the needs and objectives of the screening program. The "cream," so to speak, has been "skimmed" from materials available through seed houses and Plant Introduction Stations. Botanic gardens will continue to be a useful source of seed of species not practicably obtainable from the wild.

Collecting plant samples from natural stands for utilization research poses difficulties not common to plant collecting for herbarium use or to propagule collecting for crop breeding programs. If the sample to be collected is whole-plant material for fiber and pulp evaluation, the problems are not serious. The requirements in this case are that the plants (annuals and biennials) be at physiological maturity or beyond, dried to air-dry weight, and that 5 to 10 pounds of dried material constitute a sample. Seed collecting, on the other hand, is a more exacting and tedious task. The minimal amount for purposes of analyses is about 2 ounces. With this small amount the chemist is restricted and obtains primarily quantitative data on major constituents. With a pound sample additional work such as preliminary oil characterization research, amino acid composition studies, non-starch carbohydrate gum investigations, as indicated, is possible, leaving sufficient material for repeat analyses if necessary. Also, a pound of seed is usually sufficient to provide for initial crop increase and evaluation plantings where these appear to be warranted by the analytical results. Anyone who has collected seed from natural stands can appreciate the difficulties involved in harvesting as much as an ounce or two, not to mention amounts up to several pounds.

Usually seed collecting requires that the collector harvest from several populations, perhaps some distances apart, increasing the chances for mixed collections. It is imperative, therefore, that the collector be a good field botanist with an awareness of the kinds and nature of variation likely to be found in naturally occurring populations. Voucher herbarium specimens representing each analytical sample must be carefully selected and properly prepared. The collector's field notes can be of much benefit to later crop evaluation studies and

it is highly desirable that he have a good grasp of plant ecology. He must also be imaginative in devising methods and tools to facilitate harvesting and handling of seeds of all shapes, sizes and weights, inclosed in, imbedded in, or attached to, structures even more variable than the seeds themselves. The field collector is provided with a list of *desiderata*, but he must also use his own judgment when collecting for a new crops screening program. Good judgment is, in part, an appreciation of potentialities which can be developed by the modern plant breeder. The ideal collector for this program is, in short, a high-caliber botanist with a real interest in economic plants. So far, it has been possible to acquire good service on a part-time basis through arrangements with staff botanists of colleges and universities and by using plant explorers on the staff of the New Crops Research Branch.

SOME PROMISING LEADS

Annual pulp crops. General requirements for a species to be considered as a potential source of paper and dissolving pulps are: (1) high annual yield of cellulose per acre, (2) desirable chemical composition for pulp, and (3) desirable physical dimensions for pulp fibers. Beyond these general requirements many specific factors (the ultimate product to be made from the pulp and the pulping methods to be employed) become involved. In the initial stages of a pulp screening program it is possible to classify the samples assayed only into groups having greater or less general pulping potential. Refined evaluations for specific uses of those having high general potential will come through more costly and time-consuming developmental studies.

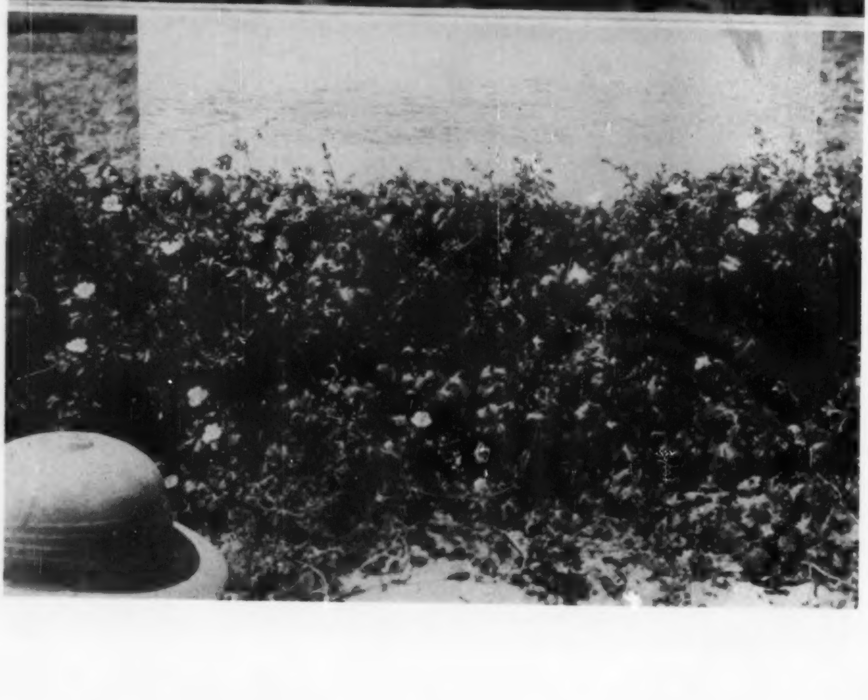
Among those revealed by the screening program thus far to have high potential are kenaf (*Hibiscus cannabinus*) (Fig. 2), sunn hemp (*Crotalaria juncea*), sorghum (*Sorghum vulgare*), and sesbania (*Sesbania* sp.). These are now ready to move into secondary stages of evaluation through crop production studies and pulping tests.

New oilseeds. Results of the chemical screening program for new oilseeds are highly promising and indicate that this is one of the most fertile areas for new crops research. The objective is to find *new* or *unusual* kinds of oils that will not compete with our present abundant vegetable oils like soybean, cottonseed, peanut and corn.

By October, 1958, somewhat over 1,000 seed accessions had been analyzed for protein and oil content. Of these, 13% had 60% or more oil and protein; 7.5% contained 40% or more protein; and 27% contained 20% or more oil.

Of those seeds with 20% or more oil, 178 have been analyzed for oil composition and of these 151 were shown to have oils somewhat different from our common vegetable oils. This group, with unusual fatty-acid composition, is of greatest interest in our search for new industral oils. Because of program limitations only a few of the most promising of these oils and their source species are moving into secondary stages of evaluation. Preliminary crop evaluation and seed increase work are underway. Related species and genera will, meanwhile, be given priority in the screening program on the chance that even better sources of these unusual oils will be found. Basic compositional and developmental research to further refine evaluations of these oils in terms of spe-

Fig. 2. Kenaf (*Hibiscus cannabinus*) planting at the Glenn Dale Plant Introduction Station, Glenn Dale, Maryland. Most varieties of this species will not produce seed in the latitude of Glenn Dale but continue vegetative growth until frost. This is a desirable feature for an annual pulp crop where maximum cellulose production is the goal. Seed can be produced in the deep South.



cific properties and uses is being initiated in Utilization Research.

Dimorphotheca aurantiaca (Fig. 3) (Compositae) contains one of the most promising seed oils discovered in the screening program. The oil of this species contains about 60% of dimorphecolic acid, a *hydroxydienoid fatty acid* not previously known to occur naturally. This fatty acid seems to have valuable properties for a number of large industrial uses (2), (8).

Momordica balsamina (Fig. 4) (Cucurbitaceae) seeds contain about 26% of an oil similar to tung oil. This tropical annual vine may be well adapted to parts of our South and Southwest.

Many species in the family Cruciferae have been revealed by the screening program as having high amounts of erucic acid in their seed oils. Six or seven million pounds of rape oil, also high in erucic acid, is imported annually, and about 1.5 million pound of rape seed is domestically produced. Much developmental work still needs to be done on high erucic oils to determine their true potential as industrial raw materials. On the other hand, the screening program has provided the plantsman with numerous possibilities for developing superior crop sources for this type of oil.

High petroselinic acid oils provide another example of a chemically related group of oils found in closely related plants. Oils of this type are found almost exclusively in the Umbelliferae. A pattern of development similar to that for high erucic oils is indicated for this group.

High nonconjugated diene oils have also been discovered in considerable numbers in the screening work. Like safflower, many of these are members of the Compositae. *Rudbeckia bicolor* (Fig. 5), a well-known ornamental, is one of the more promising producers of nonconjugated diene oils.

Oils of high iodine value (high trienoic acid content) have been found in three plant families, the Labiatae, the Cruciferae, and the Euphorbiaceae. More than a dozen of these have iodine values equal to or exceeding those of linseed oil.

Fig. 5. Coneflower (*Rudbeckia bicolor*), Lincoln, Nebraska. This annual is a familiar ornamental. The seed contains about 30% oil with a diene content of about 76%.

Fig. 3 (above). Cape marigold (*Dimorphotheca aurantiaca*) in experimental plot at Lincoln, Nebraska. This perennial, native to South Africa, is widely grown as a long-season annual ornamental. The achenes are broadly winged and of light weight. Successful crop development will require breeding and selection for larger, wingless achenes.

Fig. 4 (below). Balsam apple (*Momordica balsamina*) in experimental plot at College Station, Texas. This annual vine is native to the Tropics and subtropics, but appears to thrive in warm temperate regions.

Fig. 6. Crown daisy (*Chrysanthemum coronarium*), Lincoln, Nebraska. Other species of this familiar genus are being screened for unusual seed oils. Varieties of *C. coronarium* are being tested for possible correlation with epoxy acid content.

A new epoxy fatty acid, coronaric acid (5), has been discovered in the seed oil of *Chrysanthemum coronarium* (Fig. 6). There is considerable variability in the amount of coronaric acid present in the oil among different seed accessions of this species. Varieties may be found which have several times the coronaric acid content of 10-15% found in accessions to date. This constitutes another worthwhile lead to follow in our search for new industrial crops.

ACKNOWLEDGMENTS

The authors are indebted to J. L. Creech, Beltsville, Maryland; R. G. Reeves, College Station, Texas; and J. H. Williams, Lincoln, Nebraska, for photographs used in figures 2-6.

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Rakkyo or Ch'iao T'ou (*Allium Chinense* G. Don, Syn. *A. Bakeri* Regel) A Little Known Vegetable Crop

LOUIS K. MANN[1] and WILLIAM T. STEARN[2]

"Economic necessity is the mother of our inventions in food. We eat crabs by preference, and often eat barks by necessity," a modern Chinese author and scholar, Lin Yu-tang, has written of his people. "We are too over-populated and famine is too common for us not to eat everything we can lay our hands on." Thus there can be few plants native to eastern China whose edibility and palatability have not sometime been tested in harrowing times of famine. This "positively exhaustive experiment on edibles" extending well over 3,000 years has led to the great variety of vegetables derived from wild plants native to eastern Asia which are cultivated in China and Japan. A teeming and practical people, the Chinese learned long ago to husband the fertility of their agricultural soils and, their holdings being usually small, they developed methods of cultivation which belong not so much to farming, by European and American standards, as to market-gardening. This East Asiatic concentration of effort upon limited areas means that individual plants often receive individual attention, and a diversity of vegetables which cannot well be fitted into large-scale western farming can be handled successfully by the truck-gardener. The garlic (allium) crops of eastern Asia belong to this category. The most important of these is the Welsh onion or onion-leek (*Allium fistulosum*). Prokhanov (1931) called attention to others, among which Kiu ts'ai or Chinese chives (*A. tuberosum*) is a widely esteemed salad crop (cf. Stearn, 1946). Strangely enough, however, the importance for pickling of another species, known in Japan as rakkyo and in China as ch'iao t'ou, seems to have been almost completely overlooked by western authors, including Prokhanov, although many tons are exported every year from China and Japan. This species, now identified as the obscure *A. chinense* G. Don (*A. bakeri* Regel), has apparently long been cultivated for food in the East. There is little information in western literature about it as an economic plant. In the following account its cultivation, morphology and vernacular names are discussed by L. K. Mann, its nomenclature, synonymy and botanical history by W. T. Stearn.

Plant Characteristics

Allium chinense is easily distinguished from the alliums commonly grown in our gardens (cf. Moore, 1955). The plants form dense clumps (fig. 1) and look rather like chives (*A. schoenoprasum* L.). The leaves are slender, hollow and thin-walled like those of chives, but differ in that they are 3- to 5-angled (i.e., not so smoothly round), less stiffly erect, and are bright-green rather than blue-green. A leaf cross-section (fig. 3, above) shows clearly the angularity of the leaf and its thin wall with the larger vascular bundles protruding into the central lysigenous cavity. A higher magnification (fig. 3, be-

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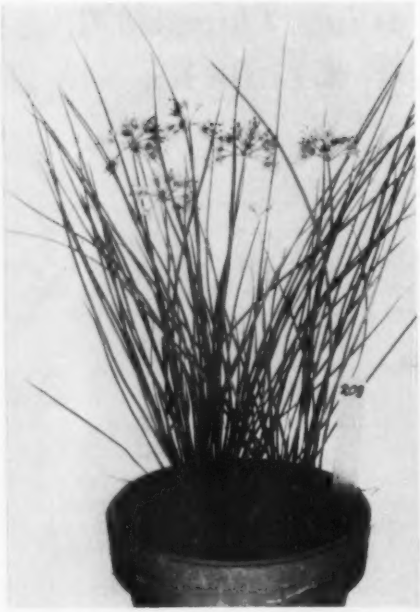

Fig. 1. Flowering plants of *Allium chinense* grown from bulbs purchased in the Chinese district of San Francisco. The pot was placed on its side for photographing, and the leaves appear more stiffly erect than they should.

low) reveals the distinct layer of short palisade cells with the laticifers at its inner edge. Most of the parenchyma within the palisade layer is chlorenchymatous and the bundle-sheaths are not conspicuous.

At Davis, California, as in Japan, the leaves of rakkyo die down in summer. In late summer the inflorescences appear, accompanied or soon followed by the new leaves, and the plants remain leafy until the following summer. *Allium tricoccum* Aiton, of the eastern U. S., also flowers after the leaves wither, but new leaves do not appear until the following spring. The growth pattern of rakkyo is unique among the *Allium* species known to me. The summer dormancy is not occasioned by drought since it occurs in well-watered plants. Apparently rakkyo does not always flower, even when growing vigorously. In 1958, field-grown plants at Davis initiated flowers but these aborted before emerging, possibly because irrigation was withheld after the tops died down.

The well-developed ovoid bulbs are quite distinctive (fig. 4). In cross-section (fig. 2) these resemble small bulbs of the common onion (*A. cepa*), but differ in that they contain none of the bladeless

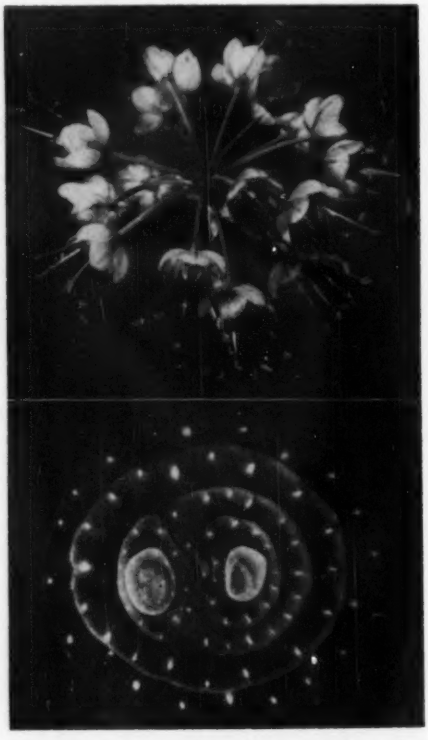

Fig. 2. Inflorescence and cross-section of a bulb of *Allium chinense*. The degree of opening of the flowers, the obtuse perigon segments and the long-exserted stamens and style are characteristic. The bulb cross-section was cut in November, 1958 at the end of the summer rest. The two outer sheaths bore leaves (now withered) during the season of 1957-58. The blades of the leaves within these were emerging and would have been the leaves of the 1958-59 season. No scape was present ($\times$ 4).

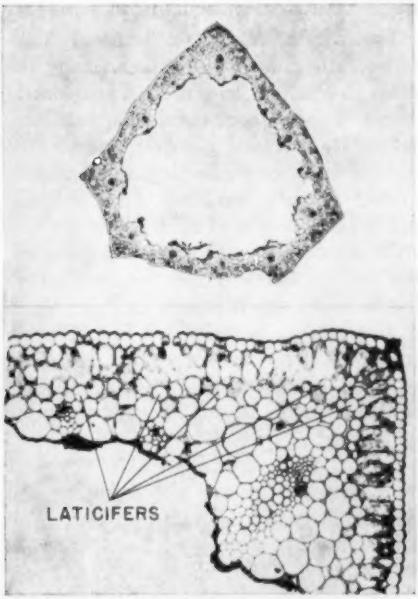

Fig. 3. Leaf blade cross-sections of *Allium chinense*. The upper figure shows the angular shape of the leaf, its large central cavity and uniformly spaced vascular bundles. The higher magnification shows the single palisade layer and the laticifers bordering its inner edge. Upper figure × 16; lower × 72.

scale leaves characteristic of *A. cepa,* all scales being the sheaths of blade-bearing foliage leaves. In the bulb shown (sectioned in late summer, 1958) the outer two scales had green tops in the 1957-58 season and the scales within these would have produced green tops in the 1958-59 season. The two inner buds shown would have become separate bulbs on collapse of the two outer scales. Sections closer to the root-plate show as many as four buds during the summer dormant period and during a season's growth (summer to summer) the cultivar shown in figure 1 frequently produced eight bulbs from a single planted bulb. These groups of bulbs remain attached to a common stem but this stem never becomes elongate or rhizome-like as in *A. tuberosum* Rottler.

The flowers (fig. 2) are lavender with long pedicels, obtuse perianth segments and long-exserted styles and stamens. In flowers of plants grown at Davis, the outer stamens have two well-developed teeth on either side of the filament at the base but, as noted later, this is a variable character. The flower stalk, as in all alliums, is terminal on the main axis and, since the leaf blades of this axis wither before the inflorescence emerges, i.e., with the onset of the summer rest period, the new leaf blades which appear with the inflorescence in the fall are from *lateral* buds and their sheaths do not surround the base of the scape. This mode of growth serves to differentiate rakkyo from many species in which the functioning leaves and inflorescence arise from the same axis, and hence in which the sheaths of the foliage leaves encircle the scape.

The only chemical analyses of rakkyo appear to be those reported by Read (1936) who gives the following percentage composition of the bulbs, based apparently on fresh weight: protein, 2.2; fat, 0.3; carbohydrate, 13.1; and ash, 3.8. These data give little information on the eating quality of rakkyo, a quality which must account for the fact that the Chinese and Japanese, while using *A. cepa,* do not accept it as a substitute for rakkyo. Taste is difficult to describe, but two characteristics of rakkyo are outstanding: a delightfully crisp texture in both the fresh bulbs and pickles, and a strong onion-like but distinctive odor. I am sure anyone well acquainted with rakkyo pickles could distinguish them immediately from those made from any other cultivated allium. As with many foods, rakkyo is enjoyed most by those who have eaten it since childhood; friends to whom I have offered rakkyo pickles usually find them pleasant, but none of the many bottles I have opened has been completely consumed before spoiling from old age!

Cytology

As noted below, Dr. Kumazawa has not observed seed set in rakkyo. I have pollinated greenhouse plants without success, but these were clonal and may have been self-incompatible. Kurita (1952), reviewing the literature on the cytology of *A. bakeri*, notes that both diploids and tetraploids have been reported, and that irregular divisions were observed in the pollen mother cells of a tetraploid form. Kurita figures the chromosomes of *A. bakeri* and concludes from his own observations that it is an autotetraploid, $4n = 32$. *Allium virgunculae* Maekawa and Kitamura, a closely related plant according to Ohwi (1956), is a diploid, $2n = 16$ (Kurita, 1953). Whether all cultivars are tetraploid is not known, but this could readily account for the observed sterility of some clones.

Use and Cultivation in California

My first encounter with *A. chinense* was a purchase made several years ago of bulbs of an unknown plant—by appearance and odor obviously an onion—from a produce market in the Chinese district of San Francisco. These bulbs grew vegetatively for about two years, the plants superficially resembling chives in their narrow, fistulose leaves but developing elongate bulbs some three-fourths inch in diameter. In 1956 similar plants were collected by Dr. William Sims, Extension Specialist in Vegetable Crops at Davis, from the farm of Mr. Jack Chin near Castroville, California, where they were being grown for the fresh market in San Francisco. At about the same time Dr. G. L. Stebbins, through the courtesy of Dr. S. Kitamura, Botanical Institute, Kyoto University, brought me a plant from Japan which appeared identical to the previous collections. It was labeled *A. bakeri*. In September 1957, the collections from San Francisco and Japan both flowered for the first time and their identity as *A. bakeri* was confirmed.

Statistics on rakkyo production in California are difficult to gather, since the plant is a minor crop used almost exclusively by the Japanese and Chinese. These people know it well, however, and buy the pickled bulbs or make pickles from bulbs grown in their gardens. In California pickled rakkyo is sold in all towns or cities with any considerable oriental population, not only in Chinese and Japanese stores but in many supermarkets as well. Much of this rakkyo is re-bottled in California from bulk shipments from Japan (in 26 lb. wooden, bamboo-bound tubs), but some is also imported in small bottles ready for marketing.

So far as I have been able to determine, the pickles are not manufactured commercially in California and, as demand for fresh rakkyo is very limited, the rakkyo grown in California is mostly in home gardens. This home-grown rakkyo may be pickled or, like the fresh rakkyo on the markets, used in cooking special dishes. On the San Francisco market fresh rakkyo costs almost twice as much on a weight basis as the imported, bottled pickles, so I doubt that it would ever be purchased for home pickling. Mr. Jack Chin and Mr. Ray Chin, near Castroville, California, grow about two acres of rakkyo each year, most of which is sold for the fresh market in San Francisco. A small acreage is reported to have been grown near Fresno, California, but I have not seen this nor do I know of other commercial plantings.

The Chin brothers plant their rakkyo in April, one or two bulbs every eight to nine inches in the row, in two rows about 12 inches apart on beds spaced 40 inches apart with irrigation furrows between. This pattern of planting is typical of many irrigated row crops in California. The soil is light, and fertilizer is applied before planting and two or three times thereafter. In August, the soil is banked up three to four inches deep around the

plants so that when harvested in December or January, the stems will be white for several inches above the bulbs. The plants multiply vegetatively, each plant producing perhaps thirty bulbs before harvest. Yields are estimated at three to four tons per acre, although accurate records are not available. Harvesting is done by hand and the plants are packed in crates with several inches of stem attached. A plot of sufficient size to replant the harvested area is left. Reproduction is strictly vegetative as seed is not produced.

In Hawaii, as in California, consumption is largely satisfied by the imported pickles and Dr. Donald C. McGuire, Associate Olericulturist, University of Hawaii, informs me that the total acreage, including home gardens, is between one-fourth and one acre. He adds that "During the war, however, there was a great deal more of it under cultivation, since imports were cut off. . . . All the techniques of growing and preserving used here have been adopted from the appropriate Japanese practices. . . ."

Fig. 4. Pickled bulbs of *Allium chinense*. The bottles contain pickles imported into the U. S. from Japan; the label is from a can exported from Hongkong and purchased in London. The bottle on the left and the can are for the Chinese trade; the other two bear Japanese labels. The sample at the extreme right was imported already bottled and contains the preferred quality small bulbs known as hana-rakkyo. The two bottles of larger bulbs, like most rakkyo, were bottled from bulbs imported in bulk. The inset at the upper right is the Chinese classical name, *hsieh*. The Chinese common name, *ch'iao t'ou*, appears above the bulbs on the can label, and the Japanese name *rakkyo zuke*, i.e. pickled rakkyo, in large characters on the center bottle.

The larger part of the rakkyo imported into the U. S. probably is consumed in California, since over half of the total Japanese and Chinese population of the continental U. S. resides here (U. S. Bureau of Census, 1957). Hawaii, with over 80% as many Japanese and Chinese as the U. S., consumes a large part of the U. S.-Hawaiian imports. Canada, Peru, Mexico, and especially Brazil have large Japanese populations (United Nations, 1956; Normano and Gerbi, 1943). Their consumption of rakkyo (except for Brazil) would account for the export figures from Japan as given later.

Use and Cultivation in Japan

In 1957 Mr. Keishi Urano, Chief, Kikyogahara Branch of Nagano Agricultural Experiment Station, Shiojirimachi Nagano Prefecture, visited Davis and I discussed with him the production and use of rakkyo in Japan. Since that time I have received further information from Dr. Saburo Kumazawa, Director, National Kyushu Agricultural Experiment Station, Fukuoka Prefecture, and from Dr. Tadayoshi Sugiyama, Faculty of Agriculture, University of Tokyo, Tokyo. On the basis of information which these people have so kindly supplied, I have compiled the following summary of rakkyo culture and use in Japan.

Though apparently grown in Japan for many centuries, rakkyo is a minor crop and little has been published on its agricultural production.

Dr. Kumazawa states that rakkyo is grown extensively in Japan and in central and southern parts of China. It is less common in the South Sea Islands and only occasional in Manchuria and North China. He adds, ". . . cultivation of rakkyo in China is most flourishing at Chianghsi and Hunan Provinces, and its wild type can be found in the mountain regions of Chiangsu and Chechiang Provinces. It is said that the plants growing wild can also be found in Indo-China.

"The product in South China is exported to the South Sea Islands from Amoy and Swato after being pickled in brine. It is also gathered and dispersed at Singapore and Saigon. In Central China rakkyo is sold raw or for manufacturing. There are small acreages in North China where they are distributed from Honan to Shantung. It can winter in Manchuria so is cultivated there."

The 1942 census (more recent figures are not available) showed over 11,000 acres of rakkyo in Japan, and though distributed throughout the country it is grown mainly in the south. To quote again from Dr. Kumazawa, "More than half the rakkyo produced is used for household processing and marketable products are produced largely in Fukui, Toyama, Kagoshima, Chiba and Ibaragi Prefectures. In the Fukui and Toyama Prefectures it is cultivated in sand dunes along the Japan Sea. This production is almost entirely for canning. On the other hand, rakkyo at Kagoshima, where the bulbs can be harvested in April or May, is especially appropriate for early marketing."

Our common onion (*A. cepa*) is not of importance as a pickle in Japan and is not exported. Rakkyo is exported mainly for Japanese living abroad and to southern Asia for use in curries. Dr. Kumazawa furnished the census for rakkyo export (Table I) from Japan.

The varieties of rakkyo grown in Japan do not bear seed, plants being increased by bulb divisions. These are planted between August and September and make their growth during the winter and spring. In early summer the leaves wither and the plants become dormant; it is during this period, May to August, that the crop is harvested. In Fukui and Toyama Prefectures, rakkyo may be harvested after its second year of growth in order to obtain large numbers of the small bulbs desired

TABLE I
EXPORTS OF RAKKYO FROM JAPAN, 1957

Destination	Barrels	Per Barrel	Tons
U.S.A. (including Hawaii)	13,548	26 lbs.	176.0
Canada	506	26 lbs.	5.5
Peru	102	26 lbs.	1.6
Mexico	40	26 lbs.	0.5
Okinawa	3,067	11.3 kg.	38.1
Singapore	7,102	110 lbs.	390.6
Malay	3,041	110 lbs.	167.2
Hong Kong	794	110 lbs.	43.7
Guam Island	511	26 lbs.	6.6
South Sea Islands	78	26 lbs.	1.0
Borneo	50	110 lbs.	2.8

for high-quality pickles. Here the land is cheap (dune land) and the plants need little care during their summer dormancy.

Bulbs may be planted 8 cm apart in rows 60 cm apart or, since much is raised for local or home consumption, may be planted among or around other crops. Rakkyo responds well to fertilization and can be grown in poor sandy or reclaimed soils where it is commonly fertilized with 100 pounds of N, 85 pounds P and 100 pounds K per acre, mostly applied at planting but half of the N added during the winter after the crop starts growing. Some compost may be used in addition. Light or sandy soils facilitate harvesting and it is believed that these soils favor the formation of the small sub-divisions preferred for pickling. Soil may be banked around the necks of the plants to keep them white.

The average yield in Japan as indicated by the 1942 census was 2,907 kg per acre (2.2 tons per acre). The average yield for Okinawa is near five tons, and under the best conditions in southern Japan yields of five to eight tons might be expected with lower yields in the north.

As with many minor crops, local strains are common but the named cultivated varieties (cultivars) are not many. Three principal cultivars are now grown in Japan: *Yatsubusa* which produces many small off-sets and is characterized by a narrow neck, inferior quality, and low yield; *Rakuda* which forms few but large lateral bulbs and yields well; and *Tama-Rakkyo* (meaning ball-type rakkyo) which Dr. Kumazawa has introduced from Formosa. Tama-Rakkyo has narrow foliage and forms many pure white lateral bulbs of good appearance and superior texture. It is gradually replacing the older cultivars. The small-sized, high quality bulbs of Tama-Rakkyo make the 2-year culture practiced with the older types unnecessary.[1]

Rakkyo is fall flowering and all cultivars flower if not harvested, sometime after the new crop is planted. Dr. Kumazawa has not seen seed and believes that rakkyo may be completely sterile.

With respect to use, Dr. Kumazawa states, "It is said that as long as 3,000 years ago rakkyo was used as a drug in China. Nowadays rakkyo is consumed in China fried with a little oil, as pickles (with or without sugar or honey), or as brine pickles. But in Formosa all rakkyo is used after being boiled. In southern Asia brined rakkyo is reprocessed with vinegar and eaten with curry cooking. In Japan it is consumed for pickles only."

Rakkyo vinegar pickles are generally home made in Japan and are used year

[1]Through the courtesy of Dr. Kiyoshi Kawara, Chief, Agr. Imp. Sec., Kagawa Local Govt., Tenjinmae, Takamatsu-shi, Japan, we now have about twelve Japanese clones growing at Davis.

round. There are two steps in making vinegar pickles—the bulbs are first processed in brine and are then converted into vinegar pickles. To pickle rakkyo bulbs, place 2.5 parts (by volume) of bulbs in 1 part of approximately 30% brine, bring to a boil (sometimes boiling is omitted), cool, cover with a weight and let stand one week. Then spread the bulbs under sunshine for half a day and cut away the roots and tops. After this pre-treatment a mixture of equal parts of vinegar and sweet sake is made up with about 40% sugar, boiled, and poured over the bulbs until they are thoroughly covered, a piece of red pepper is added and the pickles are sealed in bottles. These pickles keep very well. A little soy sauce may be added to give an amber color, the product being called Bekko-Zuke (tortoise-shell-colored pickles). The highest quality pickles are sold in small bottles as Hana-Rakkyo (flowering-rakkyo).

Dr. Sugiyama gives some variation on the above: "Tops and bases of the bulbs are removed with a knife, and the trimmed bulbs are thoroughly washed. After draining they are put into brine for several days, then transferred to vinegar and sugar (sweet pickle) or to vinegar and salt (sour pickle). It is said that the commercial products contain saccharine. When packed in glass bottles for commercial sale, they are sterilized by heat after being stoppered. The pickles for home use are never cooked and keep well for a long time. I know this process well, since my mother used it herself every summer while I was a child." Undoubtedly there are many variations in this process, particularly for home pickling.

References to Use for Food

It is surprising that there are so few references in the American or European literature on the use of rakkyo for food. Standard works such as those of Bailey (1941), Sturtevant (1919), Chittenden (1951), Bois (1927-37), Chouard (1947), Grey (1937-38) and Holland (1937) do not mention it. Helm's (1956) systematic account of condiment and food species of *Allium* includes others used in Asia but not *A. bakeri*.[1] Nor do Millan (1952), Stearn (1946, 1956), Moore (1955) and Porterfield (1951) include it. Prokhanov (1931), as noted below, dismisses it with a few words. *Allium bakeri* is described in many floristic works but again with little account of its use for food. Makino (1956) states that the bulbs are pickled for eating and Lecomte (1934) that it is intermediate in flavor between garlic and onion. References specifically on food use include Kumazawa's (1956) excellent description of its cultivation as a vegetable in Japan, its listing in a table of food plants by Akemine (1931) and a brief description of Tanaka (1895, p. 23): "The small bulbs of the size of a thumb are eaten boiled or preserved as pickles in an air tight vessel in a boiled mixture of *sake* (rice-beer), vinegar and soy. They are eaten after two months thus steeped." Sonohara *et al.* (1952) list it as "cultivated for food and drugs."

Vernacular Names

In California, as well as in Japan, *rakkyo* (ra-kyó) is the most common vernacular name for *A. chinense*. *Rakkyo Zuke,* i.e. pickled rakkyo, is a common label on bottles, as are the English renderings *Japanese Scallions, Chinese Scallions* or *Pickled Scallions.* Read (1936) gives the name *Garden Shallot,* and both Read and Kumazawa (1956) give *Baker's Garlic,* evidently a simple translation of the scientific name *Allium bakeri.* There are variations in the spelling of rakkyo—*rak kioo* or *rakkiyo* (Franchet and Sava-

[1] *A. chinense* G. Don is listed by Helm but only as an obscure cultivated plant. The name *A. bakeri* will be used in much of the following discussion as it is the name in the pertinent literature.

tier, 1879), *lakkio* (Matsumura, 1915) and *rakkio* (Tanaka, 1895). The latter author also lists *giyoja-biru*. Dr. Sugiyama informs me that this means "ascetic's allium" (*gyoja*: ascetic or ascetic devotee; *biru* or *hiru*: a group name of the plants belonging to *Allium*), and is a synonym not used by contemporary Japanese. Rakkyo also forms a part of the name for other species: *Yama Rak kioo* (Franchet and Savatier, 1879) or *Yama-rakkyō* (Matsumura, 1895), i.e., mountain rakkyo, for *A. japonicum* Regel [= *A. thunbergii* G. Don; cf. Stearn, 1946]; and *Chishima-rakkyō* (Matsumura, 1895), i.e., Kurilian rakkyo, for *A. lineare* L. [probably *A. splendens* Willd.].

In Okinawan, the name is *datcho* (Sonohara *et al.*, 1952), and Loureiro (1790) renders the Anamese name as *kieu*.

The Chinese common name of *A. bakeri* appears on products prepared for the Chinese trade, such as the left-most bottle and the can label of figure 4. The name consists of the two characters above the two bulbs on the can label and below the LL of the word *scallions* on the bottle. Read right to left, these may be romanized as *ch'iao t'ou* (Mandarin) or *k'iu t'au* (Cantonese). In addition to this common or household name, there is a learned name used in the Chinese Classics and in botanical literature which, as indicated below, is undoubtedly to be associated with *A. bakeri*. The symbol for this name is shown in the upper right corner of figure 4 and in figure 5. In modern standard Mandarin (modern Pekingese) this symbol is rendered *hsieh,* in old Mandarin (still in use in some areas in Central China) *hiai.* In addition there are several derived terms using *hsieh* or *hiai,* e.g. *hiai shi* for fruit, and *hsieh pai* or *hsieh t'u* for the lower white part of the plant or the small white bulbs used for pickling (Bretschneider, 1895; Smith, 1871; Stuart, 1911).

The Chinese names of cultivated or useful plants are of particular interest to the botanist. Not only does their occurrence in an extensive early literature give information on plant origins and migrations, but they may also be guides to identity of more value than the Latin binomials applied by early botanists.

From the evidence supplied by Bretschneider (1892, 1895) and Laufer (1919) it is evident that *hsieh* represents, to quote Laufer, ". . . an *Allium* anciently indigenous to China. . . ." However, neither Bretschneider nor Laufer expresses a definite opinion as to what species it might be.

A number of authors have referred *hsieh* to *Allium ascalonicum,* the garden shallot. According to Bretschneider (1892), Williams' Chinese dictionary interpreted it as "the shallot or scallion, *Allium ascalonicum";* Giles (1912) follows this definition; Smith (1871), Faber (1907), and Stuart (1911) all consider *hsieh* to be *A. ascalonicum,* an identification probably suggested by the use of the bulbs. Debeaux (1877) gives *hsieh* for *A. ascalonicum* var. *sinense* Lour., a garden plant in Tché-foû.

On the other hand, *hsieh* is frequently associated with *A. bakeri* Regel. The *So moku dzu setsu* (in the 1874 and 1910 eds.—the 1856 ed. has not been seen) refers *hsieh* to *A. bakeri* as does the *Chih wu ming-shih t'u-kao* (1848) (see fig. 5 for the excellent illustration from the latter). Likewise, Tanaka (1891), Matsumura (1915), Makino (1956), and Read (1936) all refer *hsieh* to *A. bakeri.*

Prokhanov (1931) disagrees with both of these opinions and concludes that *hsieh* is the Welsh onion, *A. fistulosum* L. Helm in his recent treatment of cultivated onions (1956) follows this view.

While one cannot be sure that the word *hsieh* has been applied consistently, even by the Chinese themselves (see Faber's note in Bretschneider, 1892, p. 403), the evidence at hand suggests that its most probable connection is with *A. bakeri,* not

with *A. fistulosum.*

Laufer's (1919) reference to *hsieh* as an ". . . *Allium* anciently indigenous to China . . ." can hardly fit *A. ascalonicum* which, if present in China, is surely an introduction. To dispose of this difficulty Prokhanov attached *hsieh* to the widely cultivated and indigenous species, *A. fistulosum.* Prokhanov was not, however, aware of the extensive use of *A. bakeri* in China and Japan, and relegated it (p. 173) to a small section—"Other Cultivated Onions"—where he states: "According to the data of E. N. Sinskaia, and her data are verbal data from the Japanese people, *A. bakeri* Rgl. is cultivated in the mountains of the island of Kyushu." He further discounted Hooper's (1929) tentative but reasonable identification of a Malayan drug as *A. bakeri,* believing it to be *A. fistulosum.* Most references to *hsieh* speak of it as a cultivated plant (note the early confusion of it with *A. ascalonicum* of the West) and it is perhaps for this reason that Prokhanov associates it with *A. fistulosum.*

By attributing *hsieh* to *A. fistulosum,* Prokhanov added a second name from the old Chinese literature to this species, since it had already been identified with *ts'ung* (Bretschneider, 1892). That this one species would have two contemporary names seems questionable. Both Bretschneider and Laufer refer to evidence of *four* species of *Allium* from the older Chinese literature, and consider *ts'ung* and *hsieh* as two separate entities among the four. The symbols for *ts'ung* and *hsieh* appear together in at least two of the Chinese Classics, in one case apparently both within a single sentence (Bretschneider, 1892, p. 169, 172). Also the passage (quoted by Needham, 1954) in the *Yo-Yang Tsa-Tsu* (c. 800 A.D.) by Tuan Ch'eng-Cheu on plants as indicators of metals clearly implies their application to different plants: "Whenever there is *Ts'ung* in the mountains, one will find silver beneath; whenever there is *Hiai* one will find gold beneath."

Prokhanov presents a further argument (p. 185) as follows: Bretschneider (1892) observed *ts'ung* but not *hsieh* near Peking; Debeaux, in his flora of Tché-foû (1876-78)—an area not far from Peking—observed *hsieh* but not *ts'ung* (*A. fistulosum*); therefore *ts'ung* and *hsieh* must be the same!

The extensive use of the indigenous *A. bakeri* by the Chinese (and Japanese) makes its identification as *hsieh* seem most reasonable. Stuart's (1911) description of *hsieh* (which he believed to be *A. ascalonicum*) also applies remarkably well

Fig. 5. *Allium chinense,* a woodcut from the *Chih-wu ming-shih t'u-k'ao* (1848). The symbol *hsieh* appears on the left margin. (Photograph by courtesy of Mr. G. Atkinson from a copy at the Royal Botanic Gardens, Kew).

to *A. bakeri*: "This is the ordinary garden *shallot;* the slight variation from the European variety being produced by the different method of culture employed by the Chinese. It is indigenous to China; the wild variety being readily found in the Lü mountains of Kiangsi. The seeds are usually planted in the autumn and the small bulbs separated and transplanted in the spring. It is used as a vegetable, though not so highly prized as the native leek (*Allium odorum*). The small bulbs, called . . . (Hsieh-pai), . . . are pickled, as in Europe, and they are also preserved for medicinal use in alcohol. . . ."

It is interesting that the *List of Chinese Medicines passing through the Chinese Maritime Customs, 1889,* includes 2.52 piculs [ca. 133 lbs.] of *hiai pai* exported from Amoy in 1885 (Bretschneider, 1895, p. 392). As noted above by Kumazawa, pickled *A. bakeri* is still exported from Amoy today.

Nomenclature and Synonymy

From the first publication of the name *Allium chinense,* by George Don the younger in 1827, down to the present day, its application has been obscure. Don, in his *Monograph of the genus Allium* (1827), placed it among his "species non satis notae", since he had no firsthand knowledge whatever of the plant his name was intended to designate. He merely knew that the east Asiatic plant described by Loureiro in 1790 under the name *A. triquetrum* could not be identical with the European *A. triquetrum* of Linnaeus and he assumed, rightly as it happens, that Loureiro's plant represented a new species wanting a name. This is evident from Don's protolog:—

> 112. *All. Chinense,* foliis teneribus triangularibus, umbella fastigiata, staminibus simplicibus. Allium triquetrum, Lour. Cochin. p. 202. *Hab.* in China et Cochinchina. *Bulbus* oblongus, parvus, albus. *Scapus* fere pedalis, foliis subaequalis. *Flores* dilute violacea.

The above is simply a paraphrase under a new name *A. chinense* of the account under *A. triquetrum* in Loureiro's *Flora Cochinchinensis* (1790), which reads as follows: —

> Sp. 3. ALLIUM TRIQUETRUM. α Kieu, β Kiai: Kiao theu. Differ. spec. Al. *scapo* nudo, *foliisque* triquetris: *staminibus* simplicibus. Lin. sp. 32.
> Hab; & notae. *Folia* radicalia, triangularia, sub-pedalia. *Bulbus* oblongus tunicatus, parvus, albus. *Scapus* nudus, tenuis, teres, foliis subaequalis. *Flos* dilute violaceus: *umbella* plana: *staminibus* simplicibus.
> Colitur in Cochinchina, & China.
> Allium caule triangulo. Tournef. Inst. p. 385.
> Moly parvum, caule triangulo. Bauh. Pin. p. 75.
> Usus praecipuus Culinarius. Praeditum odore, & sapore debili, nec ingrato, vices Porri agit, & variis modis praeparatum mensis apponitur. Virtus in re Medica. Emolliens, & Resolvens; valetque in tumore, & inflamatione mamillarum, si contusum cum pauco sale, & semiassum calide applicetur.

Prokhanov (1931), following Maximowicz (1859), believed this to be an inaccurate account of the species commonly known as *A. tuberosum* and he adopted the name *A. chinense* for the latter, which, however, always has white flowers. Merrill (1935) and Stearn (1946), unable to match any culinary allium with Loureiro's description, felt obliged to leave it obscure. The possibility of its being the same as *A. bakeri* did not occur to them. Had the economic importance of *A. bakeri* been earlier recognized, its agreement with *A. chinense* would have been apparent.

João de Loureiro (1710-91) lived in Cochinchina for nearly thirty-six years, principally near Hue, and at Canton for about three years, leaving there in 1781 to return to Portugal. His chief reference works while in the East were Linnaeus's *Genera Plantarum* and *Systema Naturae* and whenever possible he listed his plants under Linnaean names. Believing them to be the same as Linnaeus's he naturally repeated the concise Linnaean diagnostic phrase-names and then gave firsthand in-

formation of his own which frequently reveals that he had misapplied the Linnaean name. In identifying a culinary allium of China and Cochinchina with Linnaeus's *A. triquetrum* he was certainly wide of the mark, as Don realized.

H. F. Hance long ago indicated the bearing of the vernacular names cited by Loureiro upon the interpretation of his species and, although such names may be untrustworthy, Merrill (1935) has correctly noted that "local names for those species of distinct economic importance are much more constant and more to be trusted than are the vernacular names of numerous small herbs, grasses, sedges, weeds, and other plants of little use in the economy of the natives." Loureiro romanized the Chinese name of his "*A. triquetrum*" as "Kiai" and "kiao theu", names clearly equivalent to the Mandarin *hiai* and the Cantonese vernacular *k'iu t'au*. Less clear is Kaempfer's (1712) romanization "Kei" of the Chinese name of a kitchen-garden allium cultivated in southern Japan:—"*Kei*, vulgo *oo nira*. Porrum sectivum latifolium." Kaempfer's meaning is evident, however, as he adds to his description the character for *hsieh*, a character interpreted as applying to *Allium bakeri* by Makino (1956) and others (see above). The details given by Loureiro, e.g. the oblong white small bulb, the basal angled leaves about a foot long and equalling the scape, the flowers pale violet, the umbel flattened rather than globose, the stamens simple rather than tricuspidate, likewise fit *A. bakeri*. There is indeed no other cultivated species of eastern Asia to which they will apply. Likewise in keeping with *A. bakeri*, as the information now available about its cultivation and use in China and Japan makes abundantly evident, are Loureiro's remarks "Colitur in Cochinchina, & China" and "usus praecipue culinarius." The name *A. chinense* G. Don (1827), having priority of publication over *A. bakeri* Regel (1875), has accordingly to be adopted as the correct scientific name for the species.

The history of the name *A. bakeri* parallels that of *A. chinense* in that its typification leads back to an inadequate description published under another name. In 1847, after describing *Caloscordum neriniflorum*, John Lindley went on to note that "Mr. Fortune found another species with longer styles (102 of his Herbarium) in Chusan, with small heads of flowers not more than ten in number, and only half the size of this. We propose to call it *C. exsertum*, and to define it thus:—*C. exsertum;* foliis angustissimis planis scapo duplo brevioribus, umbella pauciflora contracta, pedicellis perianthio vix duplo longioribus, staminibus exsertis stylo filiformi brevioribus."

This might well have remained as obscure as the earlier *A. chinense* had not Lindley clearly indicated the type, Fortune 102, from Chusan, China, evidently collected there by Robert Fortune in 1845. The holotype is in Lindley's herbarium at the Botany School, Cambridge, England. Isotypes are in the herbaria of the British Museum (Natural History) and the Royal Botanic Gardens, Kew, and from these and other specimens agreeing with them John Gilbert Baker (1874) published a description clearly establishing its identity, under the name *Allium exsertum*. That name had, however, been used by George Don in 1827 for another species. In 1875 Regel accordingly gave Baker and Lindley's species the new name of *A. bakeri*.

The synonymy of the species is accordingly as follows:

ALLIUM CHINENSE G. DON

Porrum sectivum latifolium Kaempfer, Amoen. Exot. 831 (1712).

"*Allium triquetrum*" sec. Loureiro, Fl. Cochinch. 202 (1790), non L. (1753).

A. chinense G. Don, Mon. Allium (Mem. Werner. Nat. Hist. Soc. **6**) 83 (1827); Merrill, Comment. Lour. Fl. Cochinch. (Trans. Amer. Phil. Soc., n. s. **24**, ii) 106 (1935); Stearn in Herbertia **11** (1944):

238 (1946); Hou, Fl. Canton 698 (1956).

A. rakk'joo Siebold in Verh. Batav. Genoot. xii: 16 (1830), nomen nudum.

Caloscordum exsertum Lindley in Bot. Reg. **33:** sub t. 5 (1847).

"*Allium splendens*" sec. Miquel, Ann. Mus. Lugd.-Bat. **3:** 154 (1867) non Willd. (1830).

A. exsertum (Lindley) Baker in J. Bot. (London) **12:** 294 (1874); non G. Don (1827).

A. bakeri Regel, All. Mon. (Acta Horti Petrop. **3** iii) 341 (1875); Franchet & Savatier, Enum. Pl. Japon. **2:** 77 (1879); Hooker f., Fl. Brit. India **6:** 341 (1892); C. H. Wright in J. Linn. Soc. Bot. **36:** 120 (1903); Matsumura, Index Pl. Japon. **2,** i: 188 (1905); Makino in Iinuma, Somoku Dzusetsu **6:** t. 36 (1910); Makino, Illustr. Fl. Japan, 2nd ed. 747, fig. 2241 (1954).

Illustrations: Somoku Dzusetsu, ed. Makino, **6:** t. 36; Makino, Illustr. Fl. Japan, 2nd ed., fig. 2241; Wu Ch'i-chün, Chih-wu ming-shih t'u-k'ao, ic. **3:** pl. 35 (see fig. 5, this paper); Tanaka, Useful pl. Jap. ic. **1:** fig. 123; Iwasaka, Honzo zufu, **45:** 11 verso, 12 recto.

Bulbs closely clustered, attached to a short rhizome, narrowly ovoid, about 1-1.5 cm thick, the outer tunic thin, membranous, entire, white or reddish. *Leaves* usually 3 to a bulb, almost basal, arising out of a sheath 3-5 cm long from the top of the bulb, ascending, linear, hollow, 3-5-angled, to 30 or more cm long, 1-3 mm broad, about as long as the scape, glabrous; ligule present, 0.1 mm long. *Scape* terete, solid, 28-30 cm high, glabrous, devoid of leaves. *Spathe* 2-valved, membranous, persistent, much shorter than the pedicels, each valve narrowly ovate, acute, ca. 7 mm long, several-nerved. *Umbel* more or less hemispherical, to 18-flowered, loose, without bulbils; pedicels almost equal, much longer than the perigon, 1-1.5 cm long, glabrous, with bracteoles at base. *Perigon* open cup-shaped, lavender (light violet); tepals broadly elliptic, rounded, about 5 mm long, 3.5-4 mm broad, with a distinct median nerve. *Stamens* prominently exserted; filaments purple, about 7.5-8 mm long, the outer three simple and subulate, the inner three linear-subulate from a broadened base provided with 2 teeth on either side; anthers purple, about 2 mm long after dehiscence; pollen whitish. *Ovary* obovoid, smooth, without crests but with 3 low apical swellings, the nectaries covered by 3 prominent hoods ca. 1 mm long; ovules 2 in each loculus; style exserted, whitish, subulate, up to about 4.5 mm long; stigma punctiform.

The above description is based on cultivated material from Davis, California, collected in October 1957 by L. K. Mann. The three inner filaments are provided with two distinct teeth on each side whereas in Fortune's type-material they are merely shouldered or with a short tooth on each side. Such variation is known in other species, e.g. *A. lineare* L. Distribution: Central and eastern China, whence probably introduced into Japan, Indo-china and India.

Specimens examined:

CHINA. Chekiang: Chusan, 1845, *Fortune* 102 (CGE! type of *Caloscordum exsertum* Lindley, *A. bakeri* Regel; BM! K!); Shanghai, cultivated, 1885, *Faber* (K!). Fukien: Foochow, 1898, *Carles* 759 (K!). Hupeh: on cliffs, *Henry* 7493 (K!); Nanto and mountains to northward, *Henry* 3071 (K!), *Henry* 4413 (K!).

JAPAN. Kyushu: Kosido (i.e. Koseto), 1861, *Oldham* 422 (K!); Nagasaki, 1863, *Maximowicz* (BM! K!). Honshu: Yokohama, 1862, *Maximowicz* (K!).

INDO-CHINA. Tonkin, *Balansa* 4157 (K!).

INDIA. Assam: Khasia, *Hooker f.* & *Thomson* 8 (K!).

CULTIVATED IN U.S.A. California: Davis, garden of Mrs. M. Ryugo, 1957, *Mann* (Davis! BM!); Davis, Vegetable Crops Field, 1957, *Mann* (Davis! BM!).

Acknowledgments

The authors acknowledge their debt to the many individuals who have furnished information or otherwise aided in the

preparation of this paper. In addition to those mentioned in the text, we wish to thank Dr. George Taylor, Director, the Royal Botanic Gardens, Kew, for permission to use the library and herbarium at Kew. For his kind help on the Chinese names, the authors are most grateful to Dr. Yuen Ren Chao, Professor of Oriental Languages and Literature, University of California, Berkeley. The photographs in figures 1, 2 (upper) and 4 were kindly taken by Margery P. Mann. Mr. Arthur Greathead, Farm Advisor, Salinas Co., and Mr. Jack Chin, Castroville, aided in gathering data on culture of rakkyo in California; and the Plant Introduction Section, U. S. D. A., has been most helpful to us in securing living plants from abroad.

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The Botanical Aspects of Ancient Egyptian Embalming and Burial[1]

The ancient Egyptian art of embalming, a highly developed process, involved many plants and plant products. Thirty-one genera of plants have been mentioned by various writers in the operations of embalming, cosmetic application, wrapping and coffin construction. The materials employed and methods of use have interested scholars of all periods. Herodotus gave the earliest account of the various aspects of embalming.

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Introduction

The purpose of this paper is to emphasize the dominant role played by plant products in the preparation for burial of mummies and to include the name of any plant thought to have been employed in that capacity. Part I establishes the species of plants used in the preparation of the dead for burial. Part II considers some of the historical, commercial and botanical aspects of these plants as they applied to the ancient Egyptians.

For their assistance in preparing the manuscript, I am indebted to: Albert F. Hill, Richard Evans Schultes and Margaret Towle of Harvard; William S. Smith of the Boston Museum of Fine Arts; Jack Davies of Washington University (St. Louis) School of Medicine, and to Walter E. Arnold, Jr.

PART I.

Embalming

Predynastic. The origin of Egyptian embalming dates back about 5200 years to the first dynasty.[1] Before the first dynasty, it had been the custom to bury the dead in a pre-natal position in a shallow, sandy grave after evisceration and wrapping with matting, linen or skins. The warmth and dryness of the Egyptian climate seemed adequate to desiccate the body quickly and thus maintain it, in some cases, in a fair state of preservation. The body may have been dried in the sun or with the heat of a fire, however (*7*).

Classical. The most ancient (and quite accurate) account of the processes of mummification is to be found in the writings of Herodotus (20). Herodotus describes in some detail three cost-categories of embalming. He tells of drawing "out the brain through the nostrils" with a "crooked iron," after which the skull is rinsed with "drugs." Next the body is eviscerated through an incision in the flank and the cavity cleansed with "palm wine" and an "infusion of pounded aromatics." "After this they will fill the body with bruised myrrh, with cassia and every sort of spicery except frankincense, and sew up the opening." This was followed, according to Herodotus, by 70 days of soaking the body in a natrum[2] solution. It was then washed, wrapped in "cloth" and "smeared over with gum." In a less expensive preparation, "oil from the cedar tree" was injected into the bowel, the passage stopped and the body placed in natrum for the prescribed time. The pas-

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[1]See the appendix for a chronology.

[2]Natrum (or natron) is a naturally occurring mixture of sodium salts and may be obtained in a crude, solid form in several areas in Egypt, among them the Wadi-el-Natrun about 50 miles NW of Cairo.

sage was then unstopped and "such is its power (the cedar oil) that it brings with it the whole stomach and intestines in a liquid state." In the cheapest preparation, the intestines were merely cleared out with a "purge."

Diodorus Siculus (13) also discusses embalming. He mentions that the body is treated with "cedar oil and certain other preparations, and then the body is treated with myrrh, cinnamon and such spices . . . that will preserve it and give it a fragrant odor." Diodorus states that such care is taken that even the hairs of the eyelids and eyebrows remain intact after embalming.

Although the accounts given by Herodotus and Diodorus are largely accurate, there are, apparently, some errors. One of these in Herodotus is in the period (70 days) he says was required for embalming. Probably the actual embalming took only 30 days (as reported by Diodorus); the additional 40 days constituted the remainder of the mourning period.

After the viscera were removed through an incision in the flank, they were carefully embalmed with various substances. Natrum was employed as a desiccant. Coarse sawdust of "aromatic woods," (52) and sandalwood (supposedly) were sprinkled on, or stuffed into, them. It is unlikely that sandalwood was used, however, since Egypt established trade with India, the source of sandalwood, only in about the third century B.C.—long after the art of embalming had waned. The viscera were next moulded and wrapped in separate linen packets and placed in one of several places: between the legs, (50) in four canopic jars placed in the tomb, or in the thoracic and/or abdominal cavities. Budge (7) and others believe that the viscera were commonly stuffed with bitumen,[1] but the point is made by Mendelsohn (34) that the black material found in and on mummies is in all likelihood aged resin and gum-resin. Wood pitch may have been used on some occasions.

The brain was customarily removed—via a hole chipped in the ethmoid bone—through the nostrils. The skull was then rinsed with some substance, supposedly a product of cedar or juniper trees, about which there is great discussion. Lucas (29) feels that the "cedar oil" of Herodotus and Diodorus and the "cedrium" mentioned by Pliny as having been used in Egyptian embalming are actually concoctions of turpentine, pyroligneous acid and wood tar. According to the Rhind Papyri, after the skull was cleansed. . . . "Anubis as embalmer filled thy skull with resin, corn of the Gods . . . cedar oil, mild ox fat, cinnamon oil and myrrh is to all thy members."

The exact identities of "corn of the Gods" and "ox fat" are obscure. As for cinnamon, it is extremely doubtful that it could have been employed in embalming before 300 B.C. (see Part II). There is abundant evidence that resins and resin-soaked linen rags were used to stuff the cranial cavity (perhaps, also, bitumen and/or wood pitch in some cases).

Other refinements included: packing the empty orbits with linen balls or onions painted to resemble eyeballs; stuffing resin-soaked linen under the skin and subsequent moulding of the physical features (54); stuffing the ears with resin plugs (51) or onions (52).

Until recently, it was universally believed that, immediately following evisceration, the body was soaked in a natrum *solution*. But Lucas (29) argues against

[1] Bitumen is a black asphaltous material probably obtained near the Asphaltites Lake (near the Dead Sea) in Palestine. The word mummy itself is derived from the Arabic "mumia" which was given to the pitch-like bitumen (or, at least, what was thought to be bitumen) from Egyptian mummy remains. "Mummy" (that is, the "bitumen" from mummies) was, until three or four centuries ago, a standard medication for bruises and wounds.

the use of a solution and contends that natrum was used in a dry state exclusively as a desiccating agent. "The phraseology of Herodotus, Diodorus, Athenaeus and other writers makes it perfectly clear that the ancient Egyptian process of embalming the human body was analogous to that of preserving fish . . ." and in ". . . Ancient Egypt fish were preserved by drying with, or without, the use of salt" (29).

After desiccation, the body was treated with myrrh, cassia, "every sort of spicery except frankincense" (according to Herodotus); myrrh and cinnamon (according to Diodorus). Thomas Greenhill (17) claims that the cavities of the body were ". . . repleted with a composition of myrrh, aloes, cinnamon, opobalsamum (myrrh), saffron and the like." Gannel (15) mentions myrrh, aloe resin, canella (impossible: see Part II) and cassia lignea. Pettigrew (41) mentions colocynth as a component of one of the mysterious anointing balsams and Dr. J. C. Warren (62) states that a mummy he examined contained friable resins with no particular odor. The balsam, storax, was identified by Reuttner (29) in undated mummy material and Tschirch and Stock (60) mention gum mastic as one of the ingredients of mummy remains. According to the Boulaq Papyrus, the head was anointed with frankincense—as opposed to the statement by Herodotus.

The sources of the resins used are in question. Lucas (29) suggests the Cilician fir (source of Egyptian "ach wood"), the Aleppo pine, stone pine and oriental spruce. It is unlikely that oriental spruce was employed, however. Its area of distribution (North Asia Minor, Armenia, Caucasus) was much further from Egypt than other good sources of resin and was beyond the normal trade area of the Egyptians. Another likely source of resin was the Cedar of Lebanon (64).

The body cavity sometimes contained onions (one or two) (52), lichens and sawdust (sometimes cedar) (64). As the embalming art began to fail in later dynasties (circa XXI), sand, mud and linen rags were commonly employed as cavity packing and, at its lowest point, the body appears to have been merely soaked in wood pitch, bitumen or resin.

Before wrapping the body, various materials were sometimes stuffed into the limbs, neck, back, etc., in order to restore natural contours (52). The body was customarily painted over with resin before wrapping and occasionally sprinkled with "aromatic wood chips." (Pettigrew (41) says one mummy smelled of cassia and cinnamon).

Little need be said about the lower priced preparations mentioned by Herodotus and Diodorus except to say that in the lowest priced one the abdomen was rinsed out with "smyrea," a liquid which, according to Pettigrew (41), was a mixture of senna and cassia (impossible: see Part II).

Cosmetics

Although cosmetic fidelity was not of prime importance, there are many cases in which the soles of the feet, hands or the nails have been stained red. Henna was probably the commonest source of this red dye, but madder and kermes[1] may also have been employed (29). *Carthamus tinctoria is* another possibility.

During the 21st dynasty, it became customary to color the body, or shroud, of the mummy red if it were a male and yellow if it were a female. In addition to the above dyes, which were probably also used in this capacity, inorganic paints with a gum base (probably gum Arabic) were used. Dyeing is an ancient art in Egypt. Reisner (48) describes a pre-dynastic

[1]Kermes is a dye prepared from the bodies of female insects of a variety allied to the cochineal insect. These are found on several species of oak in the Mediterranean region; most commonly on *Quercus coccifera.*

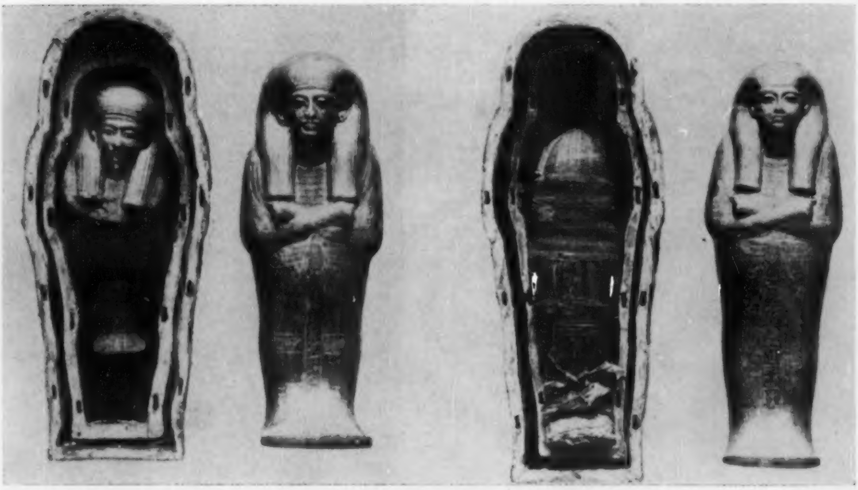

Fig. 1. Two coffins and mummies of still-born children. (After Carter).

grave in which the edges of a "shroud" mat found there had been dyed red.

Wrappings

Mummy wrappings were, almost without exception, made of linen. The wrappings, sometimes sheets but usually bandages, were approximately 3½ inches wide and 3-13 feet long and varied in texture from that of the "finest cambric" (10) to the very coarse. Two notable exceptions exist, however. In these cases the wrappings consisted of woven aloe fibers (Rameses II) and papyrus sheets (Lady Hentmehit).

The bandages were wrapped around the body in a many as 25 (62) or more layers, gum Arabic being employed frequently as an adhesive. They were sometimes soaked in resin. This permitted sculpturing of the features so as to resemble the living state (51, 54).

Coffins

Coffin construction probably began in Dynasty III. A six-ply coffin from that period was constructed from cypress, juniper, pine and sidder. A fifth dynasty tomb inscription states that ". . . His majesty commanded that there be made for him a coffin of ebony wood," but no ebony coffin has yet been discovered. During the sixth to twelfth dynasties, yew and acacia were often used. During the tenth dynasty, cedar became popular. Other woods employed were sycamore, fig and oak (oak in the shrines surrounding the coffins of Tut-ankh-amen).

The joints of coffins were fastened with wooden pegs or linen bandages and the spaces between the planks were filled with earth and gum (probably gum Arabic) (50).

Between the twelfth and eighteenth dynasties occurred two important developments in the use and construction of coffins: the series of nested coffins (Fig. 1) and the anthropoid coffin (Fig. 2). Although it was often carved from wood, the anthropoid coffin was also commonly moulded from a material like papier-maché consisting of plaster and layers of linen or papyrus. Coffins in later dynasties were varnished with a resin, the identity of which is unknown.

When the wrapped mummy was laid in the coffin, it was often "anointed" with a

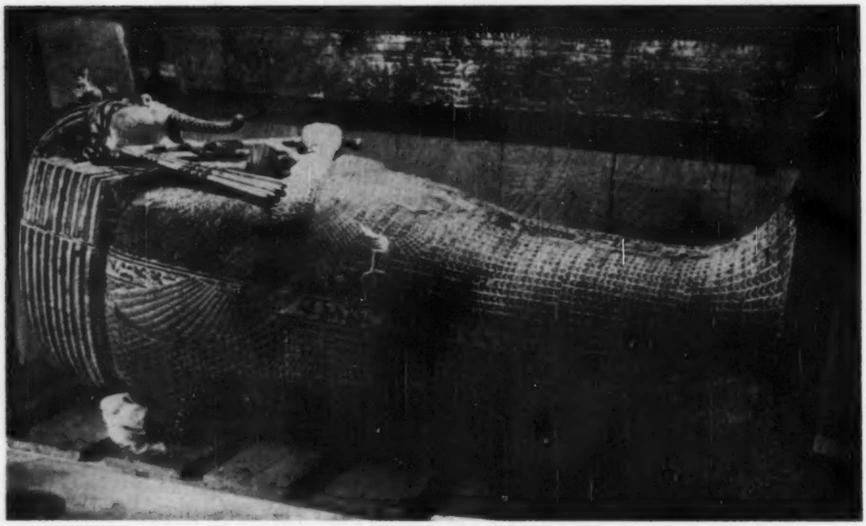

Fig. 2. Second coffin of Tut-ankh-amen. It is 6′ 8″ long; of carved heavy wood (oak?); overlaid with sheet gold on gesso; inlaid with opaque polychrome glass simulating red jasper, lapis lazuli, and turquoise. (After Carter).

viscous material which, in some cases, appears to have been wood pitch (probably from *Juniper* spp.) and, in others, a mixture of about 10% fatty material and 90% resin (29). This black resinous material was frequently the well-known "kyphi," an ointment of which Plutarch (in Isis and Osiris) states there are sixteen ingredients and Dioscorides ten. Some of these components are known with certainty. One is gum mastic (60, 64). Another, according to the Ebers Papyrus, is some product from "cyprus" (probably *C. papyrus*) (64). Others are frankincense, myrrh, juniper berries, "nebk" (*Zizyphus spina-christi*) and raisins. The "anointment" was sometimes so thorough as to "glue" the mummy firmly in its coffin.

PART II[1]

THALLOPHYTA

Lichens

Parmeliaceae

Evernia furfuracea (*Parmelia furfuracea*). The "sprout lichen" commonly grows on dead wood and tree bark, occasionally on certain species of *Pinus*. This genus, sometimes called "oak mosses," yields an extract known as "Mousse de Chene" (or oak moss resin), which is an important base in modern perfume manufacture. The essence of this extract is a phenol, lichenol.

It is not known whether the Egyptians used this lichen to pack the body cavity because of supposed preservative properties — the characteristic musk-lavender odor is not pronounced before extraction —or whether it was purely an accident that this potentially aromatic material was employed. It is known, however, that this lichen was an ingredient used in breadmaking.

E. furfuracea does not grow today in Egypt, but must be imported from the more moist Islands of the Archipelago. It is likely that the ancient Egyptians, too, imported this material (37, 39, 46, 64).

[1]A table following this part gives a summary of names and uses of plants discussed.

SPERMATOPHYTA

Gymnospermae

Cupressaceae

Cupressus sempervirens. "Gopher wood," or "cypress," of antiquity, is fabled for its durability and has been a favorite for coffin construction since the Egyptians introduced it nearly five thousand years ago. It is a tall tree, normally 80-90 feet, and its wood produces a pleasant, insect-repelling odor.

It is not native to Egypt and what few specimens grow there today are cultigens. Rather, it is indigenous to Iran and the Levant and probably reached Egypt through Palestine, Lebanon or Latakia.

Its remarkable lasting properties and durability were spoken of by Pliny (43) ("Pine and cypress are the strongest to resist rot and wood-worms") and it is reputed to be one of the four woods used in the construction of the cross upon which Christ was crucified (8, 11, 21, 27, 29, 35, 45).

Juniperus spp. Since most ancient times, junipers have been confused with (and referred to as) cedars. This complicates efforts to learn the real identity and use of both *Cedrus* and *Juniperus* from ancient records. There is at least one instance in which the Egyptians were apparently aware of some difference between the two genera, however. On one of the Karnak obelisks (Dynasty XVIII) it is written: "They have brought me the choicest products of . . ? . . consisting of cedar, of juniper, and of meru wood." There is tangible proof, however, that the Egyptians used juniper in coffin construction (earliest: Dynasty III)—probably *J. phoenicea* L. Twigs of *J. phoenicea* have been found in the Graeco-Roman cemetery at Harawa (29). Berries of *J. phoenicea* and *J. drupacea* Labill. have been found in many burials, the oldest being pre-dynastic. They were supposedly an ingredient of kyphi ointment.

Egypt has no native junipers. *J. phoenicea* is native to Phoenicia (a narrow strip of land between Lebanon and the Mediterranean) and probably reached Egypt through Byblos. *J. drupacea* is native to Syria and was, likewise, probably obtained at Byblos by the Egyptians. Post (45) also lists *J. oxycedrus* L. and *J. macrocarpa* Sibth. & Sm. as indigenous to the Lebanon-Palestine region.

The juniper is venerated by Christians as the tree that hid the infant Jesus when He and Mary were overtaken by Herod's assassins on the way to Egypt (11, 14, 29, 45, 64).

Pinaceae

Abies cilicia. The Cilician fir is native to Asia Minor and North Syria where it occurs in extensive forests on Mount Lebanon and the Antitaurus in association with the Cedar of Lebanon. According to Lucas (29) the Zenon Papyri (dated 256 B.C.) refers to the planting of 300 fir trees in Egypt.

Abies cilicia is a large tree, up to one hundred feet tall and seven feet in girth. Loret and Jacquemin (in Lucas, 29) believe that it was the source of the famous "ach resin" and "ach wood." Apparently fir was not much used in coffin-making as only one example is known and that well into the twenty-fifth dynasty (11, 29, 45).

Cedrus libani. The famous Cedar of Lebanon is a true cedar. For thousands of years its 70-100 foot height and 16-25 foot girth have inspired men with thoughts of strength and solidarity and the trees have always been regarded with what Franklin Lamb (24) calls "sacred awe." The Cedar of Lebanon usually grows in association with pines and firs. The forests were extensive in Biblical times, but only five small groves exist today—about 6000 feet up Mount Lebanon. These are under the care of a Christian sect called the Maronites.

The wood is fragrant, insect-repellent, quite durable and rot-resistant. It was

highly esteemed by the Egyptians for packing the body cavities of mummies, for many kinds of wood-work and very much so for coffin-making. It was first used in coffins sometime around the tenth dynasty and persisted well into the Ptolemaic period.

According to tradition, *Cedrus libani* was another of the four species of trees from which Christ's cross was made (11, 14, 21, 24, 45).

Pinus halepensis. The Aleppo pine is native to Palestine, Lebanon and Asia Minor. It almost never exceeds 50-60 feet in height and 12-15 feet in girth. It was rarely used in coffin construction since pine is not rot-resistant. The earliest evidence of its use in that capacity is the third dynasty plywood coffin from Saqqara. It is likely, however, that it was extensively employed as a source of resin and pitch. It is widely cultivated in the Mediterranean area today as a source of naval stores (11, 18, 29, 45).

Pinus pinea. The stone, or umbrella, pine frequently grows to a height of 80 feet and a girth of up to 20 feet and is highly valued not only by the naval stores industry, but also as an ornamental because of its picturesque umbrella-shaped crown. *P. pinea* has been widely cultivated for centuries and grows today throughout the Mediterranean area, Southern Europe and even in the British Isles. This confuses attempts to locate its origin but Post (45) feels that it is native to Asia Minor and Dallimore and Jackson (11) extend its original home from Asia Minor to Portugal.

There is no proof that this species of pine was ever used in coffin-making. It seems unlikely that it was a source of resin until the beginning of the Middle Kingdom when trade began to connect with parts of Asia Minor (11, 45).

Taxaceae

Taxus baccata. The common yew, or ground hemlock, is noted for its short, thick trunk (total height about 30-60 feet; girth, 20 feet; branches very near the ground) and the great strength, durability and elasticity of its wood. These last characteristics are responsible for its having long been used in bows.

It now occurs in many places around the world. In the Lebanon-Palestine area, undoubtedly the source of yew for the Egyptians, it is found in the hills and mountains.

Yew was first used in coffins at about the time of the sixth dynasty. It could not have been used as a source of resin since the tree is one conifer which yields no resin (11, 21, 29, 45).

ANGIOSPERMAE

Monocotyledonae

Cyperaceae

Cyperus Papyrus. The bulrush is a tall (8-16 feet) sedge once extensively cultivated along the shores of the Nile. The stem is triangular, smooth and composed of pith encircled by a tough rind. The plant grows today over a wide area bounded roughly by the 38th and 26th parallels on the north and south and by the 65th and 32nd on the east and west, but is virtually absent in the lower Nile marshes where it flourished in ancient times.

The origin of *C. Papyrus* is not generally agreed upon but Woenig (64) feels that it may have originated in Nubia and then spread down the Nile to lower Egypt. At any rate, this plant grew and was cultivated in Egypt and it was not imported.

C. Papyrus was used early in many capacities. One of the first evidences was a "reed" mat under the skeleton of a predynastic burial found by Petrie (40) at Naqara. The earliest evidence of its use as the famous papyrus "paper" dates back to the first dynasty about 5200 years ago. This was an unused roll, as mentioned by Emery in The Tomb of Hemaka, according to Lucas (29).

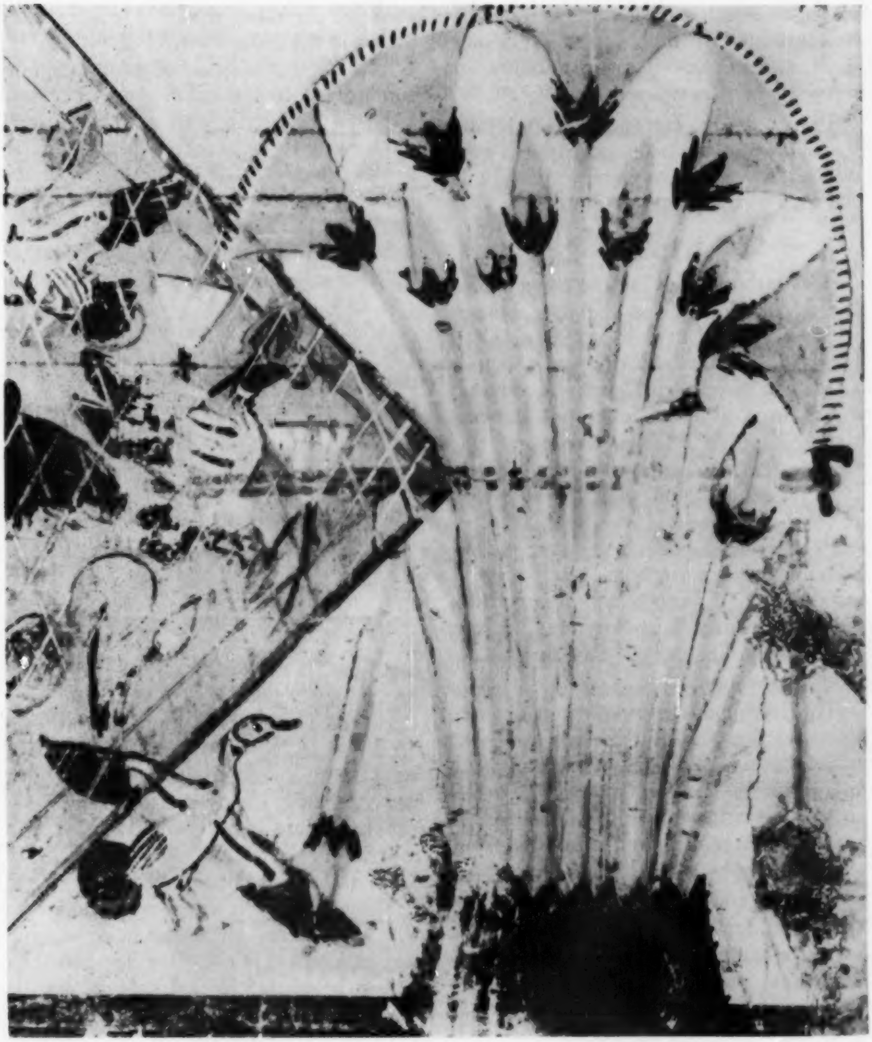

Fig. 3. Papyrus plants growing along a river bank as represented in a wall painting in the Deir-el-Bahari Temple at Thebes (circa 1400 B.C.). (Courtesy of Boston Museum of Fine Arts.)

Papyrus "paper," the commonest use to which *C. Papyrus* was put, was prepared by slicing the pith of the stem into long strips, applying some adhesive (about which there is great discussion and no conclusion) and pressing. It was then dried and impregnated with worm-repellent juices. Although papyrus was commonly employed as a writing surface for manuscripts, we have seen that it was also used for making cartonnage mummy cases, as a background for portraits to be

placed over the face of the mummy, that it contributed in some way to kyphi ointment, and that in one case a mummy was wrapped in papyrus sheets.

Pliny (43), Herodotus (20), and Theophrastus (58) discuss papyrus quite extensively and have mentioned many of the uses of the plant (8, 29, 35, 40, 64).

Iridaceae

Crocus sativus. This fall-blooming species is noted primarily for the dye, saffron, which is derived from its stigmas. There is no evidence that this dye was ever used as such by the ancient Egyptians, although it was used by the Greeks and Romans. Greenhill (17) claims, however, that saffron was used in embalming (it contains an aromatic oil which breaks down to yield a terpene and crocose), and if we can believe his account (I find no one else who mentions saffron as being used in embalming), it is then not inconceivable that saffron may have been used, at least occasionally, in dyeing the shrouds or bandages of mummies.

The likelihood that saffron was used in embalming and/or dyeing would seem to be improved by the reference to saffron in the Ebers Papyrus where (according to Woenig (64)) it is mentioned as an ingredient in a cure for "kidney trouble."

The solution to this problem is little aided by a consideration of the origin of the plant, for there is no real certainty as to the place or places in which it first developed. Most authorities suggest Greece, Italy, Asia Minor and/or Persia (12, 16, 17, 35, 45, 61, 64).

Liliaceae

Allium Cepa. The common garden onion is one of the oldest of cultivated plants. It is known today only in the cultivated state and is grown around the world. The origin of *A. Cepa* is not certain although Vavilov (61) states that its primary center was probably in Central Asia with secondary centers in the Mediterranean area and the Near East.

The Egyptians attached great religious significance to the onion since they saw reflected in it their own cosmology with the concentric spheres of heaven, earth and hell represented in the layers of the bulb. Thus, it is probable that the onions found in the body cavities of mummies were present for religious purposes rather than for any fancied preservative function (35, 61).

Aloe succotrina. According to Moldenke (35), this was the species of aloe used by the Egyptians in embalming although there are 170 species native to eastern and southern Africa and the Mediterranean basin and it would appear that there could be no great certainty as to the species employed. *A. succotrina* originated on the Island of Socotra just off the east coast of Africa at the mouth of the Red Sea. The inspissated juice has long been used in medicine as an emmenagogue and purgative.

"Aloes," a resinous material, is obtained by drying the juice of the plant. The juice is collected in animal skins after cutting off a leaf or leaves. It varies from dark, ruby-red to a yellowish or reddish brown, has a peculiar, almost fragrant odor, disagreeable taste and is easily confused with myrrh. The odor of "aloes" is due to a small amount of volatile oil.

"Aloes" contains a resinous component which would make it useful in embalming and although it is not often mentioned as having been used in that capacity by the Egyptians (Gannel (15) and Greenhill (17) mention it). Reuttner (according to Lucas, 29) detected "aloes" in some undated mummy material. There is certainty that "aloes" was used in embalming near the end of the pre-Christian period. Nicodemus brought "aloes" [from *A. succotrina*, according to Moldenke, (35)] for embalming the body of Christ.

Although Mendelsohn (34) mentions that the mummy of Rameses II was

wrapped in bandages of aloe fiber "finer than India muslin," is is doubtful that the material was actually aloe and/or that it was "fine." Aloe fiber is occasionally used in cordage and coarse textiles, but it is difficult to imagine an aloe textile "finer than India muslin." Perhaps, though, he is only mistaken about the texture of the cloth and not the fact of its use (3, 8, 29, 34, 35, 38, 55, 60).

Palmae

Phoenix dactylifera. The date palm is the primary source of food, shelter and oil for innumerable inhabitants of desert regions. It grows from the Canaries to the Sahara and Arabian deserts to Southwest Asia and since it has been cultivated throughout northern subtropical Africa since remote times, its place of origin has never been satisfactorily determined. It is known to have grown abundantly in the region between the Euphrates and the Nile during pre-Christian times; the history of the genus extends well back into the Neolithic, possibly originating near the Indus.

Although the Egyptians used the tree for cordage, brushes, roofing, food and for many other purposes, emphasis is to be placed on its use as "palm wine" which, according to Herodotus and Diodorus was used for rinsing the body cavities and viscera in embalming. It is manifestly impossible to demonstrate "palm wine" in mummy remains due to its high volatility, but the ancients are known to have prepared intoxicating beverages from both the sap and the fruit of *P. dactylifera* and there is no reason to doubt the statements of our ancient historians that these wines were employed in embalming.

To make palm wine today, a deep incision is made in the trunk just below the leaves, the sap collected and allowed to ferment. Some say it has the taste of a very light, new, grape wine. "Date wine" is prepared by fermentation of macerated dates. This process is described by Pliny (43).

Pettigrew (41) thought that the function of palm wine in embalming was that of a tannin on the skin. This is unlikely, however (8, 12, 29, 35, 36).

Dicotyledonae
Anacardiaceae

Pistacia lentiscus. The source of "gum-mastic" is a native of the Mediterranean region and may be found today in Lebanon and Palestine although there is no more reason to believe that it originated there than anywhere else in the Mediterranean area. Today the main source of mastic—described as a true resin by some and as an oleo-resin by others—is the Island of Chios off the west coast of Turkey. "Chios mastic" is conceded to be the finest variety of the very expensive mastics.

The tree is a shrubby evergreen, seldom more than twelve feet in height and much branched toward the top. Mastic is the dried resinous exudation occurring naturally or obtained through a small incision in the trunk. The thick exudation either hardens in tears on the bark or falls to the ground and is picked up. The tears are the most highly esteemed form; they come in various sizes and shapes. Mastic is transparent, ranges in color from light yellow to greenish yellow and has a slightly balsamic odor due to pinene. It is widely used today as a masticatory, perfume, flavoring, medicine and varnish in microscopy.

The Egyptians used mastic in embalming, in the preparation of kyphi ointment, which was used in embalming as well as in religious capacities (it probably had religious significance even when used for embalming), and in perfumes. Theophrastus (58) and Pliny (43) describe *P. lentiscus* in such a manner that there can be no doubt of its identity in their works (16, 18, 35, 36, 38, 45. 60).

Burseraceae

Boswellia Carteri Birdw. This shrubby, thorny bush seldom attains a height of

Fig. 4. Egyptians importing live myrrh trees from Punt as seen in the wall reliefs of the Deir-el-Bahari Temple at Thebes (circa 1400). (Courtesy of the Boston Museum of Fine Arts.)

more than four to five meters and is sparsely branched. It is native to Somaliland, Abyssinia and South Arabia. *B. Carteri* is the chief source of frankincense (olibanum), an oleo-gum-resin which is the most important incense material in the world. Frankincense may also be obtained from other species of *Boswellia*, notably *B. papyrifera* Hochst. *B. thurifera* Roxb. ex Flem. (*B. serrata* Roxb.), all of which grow in and are native to Somaliland, Abyssinia and South Arabia. The "Incense from Punt (roughly: Somaliland at the Bab-el-Madab Straits)" and "white incense" of Egyptian records are probably frankincense.

Frankincense is gathered almost exclusively by Somali Indians who even cross the Gulf of Aden to obtain it in Arabia. During the hot season they make a deep incision in the trunk and peel off a narrow strip of bark about five inches below the incision. The sap exudes, dries and forms tears on the bark which are then picked by hand. These tears are usually less than one half inch in diameter, of

irregular shape and varying in color from nearly white to yellowish to reddish-brown. The taste is aromatic and somewhat bitter. Frankincense is composed of 60–70% resin, 30–35% gum and 3–8% oil of olibanum.

The Egyptians used frankincense not only as an incense, but also in perfumes, ointments and unguents (esp. kyphi) and in embalming. It was one of the gifts brought by the wise men to the infant Jesus (16, 19, 27, 30, 35, 60, 64).

Commiphora spp. Species of the genus *Commiphora* are the source of the Balm (or Balsam) of Gilead, also called Mecca Balsam or Myrrh of Gilead, and of myrrh. They occur in the same geographical area (Somaliland, Abyssinia, South Africa) as *Boswellia* spp. and their oleo-gum-resins are produced and harvested in a manner identical with frankincense. The trees are low and shrubby, seldom more than ten or twelve feet high, with thorny branches.

It is generally agreed that *Commiphora* (*Balsamodendron*) *opobalsamum* (L.) Engl. is the source of the Balms, Balsams and Myrrhs of Gilead and Mecca. The many references in ancient writings (including Egyptian) to balms and balsams probably refer most often to the gum-resin of *C. opobalsamum,* although it is apparent that the terms were used indiscriminately for many kinds of resins, gum-resins, gums, ointments, unguents, etc.

There is much more difficulty in determining the ancient source or sources of myrrh. There are 160 species of *Commiphora* and, of these, there are two in Arabia, one on the Island of Socotra, and forty-one in northeast Africa. The species which appear to be the main supplies of myrrh are: *C. myrrha* (Nees) Engl. var. *Molmol, C. Schimperi* (Berg) Engl., *C. erythraea* (Ehrenb.) Engl. and *C. abyssinica* (Berg) Engl. According to most authorities, *C. Myrrha* var. *Molmol* is the principal source of myrrh today, but Engler says *C. Myrrha* gives no resin at all. This disagreement arises because Engler recognizes *Molmol* as a species rather than a variety of *C. Myrrha*—in opposition to most writers.

Perhaps much of the confusion may be attributed to the fact that there are two types of myrrh: herabol and bisabol. Herabol (sometimes called "true myrrh") commonly occurs in rough, eroded tears, from 2.5 to 10 cm. in diameter. It is a dull red-brown and covered with powder; it tastes bitter although its odor is agreeably aromatic. Bisabol is much like herabol in color although it is more yellowish and less dusty. It is characteristically soft and gummy. Myrrh ordinarily contains 2-5% volatile oil (bisabol goes up to 8%), 25-50% resin and the remainder gum.

The Egyptians prized myrrh very highly for use in embalming, perfumes, ointments, (esp. kyphi) and unguents. There are many references to it in Egyptian records. In the Punt reliefs may be found the description of an eighteenth dynasty expedition where ". . . the loading of the ships very heavily with marvels of the country of Punt; all goodly fragrant woods of God's-land, heaps of myrrh resin, with fresh myrrh trees . . ." is described (see Fig. 4). The Egyptians often attempted the introduction of desirable plants not native to Egypt; Tschirch and Stock (60) state that myrrh trees *were* cultivated in Egypt for a time.

Myrrh was another of the gifts from the wise men to the infant Jesus (6, 18, 19, 23, 27, 30, 31, 35, 38, 60, 64).

Compositae

Carthamus tinctoria. This is a prickly, herbaceous plant, seldom more than two to four feet high, which yields safflower (also, carthamine or bastard saffron) and safflower oil. Opinion is divided as to the exact place of origin, but most authors seem to agree with Vavilov (61) that there were three (or, perhaps, any one of three) centers; India, Central Asia and

Abyssinia. *C. tinctoria* is virtually unknown in the wild state today (Theophrastus (58) and Pliny (43) say it grew both wild and under cultivation) and this greatly confuses attempts to locate its origin. It occurs today in many parts of the world, including Egypt. It is known that *C. tinctoria* was cultivated, too, in Ancient Egypt.

There is no evidence that safflower oil, which is pressed from the seeds, was used by the Egyptians, but there is much evidence that the dye was employed, especially in dyeing mummy wrappings and shrouds. *C. tinctoria* yields two dyes; red (carthamin) and yellow. The yellow is of limited usefulness because it is soluble in water. The dye is extracted from the florets which are gathered in dry weather as fast as they begin to open. These are dried, the yellow component extracted with water and the red residue, if not used immediately, is pressed into cakes (12, 27, 29, 30, 36, 57, 61, 64).

Cruciferae

Isatis tinctoria. This species is the source of woad, a blue dye almost completely indistinguishable from indigo. It has always been accepted that the blue dye of the Egyptians was indigo, from either *Indigofera tinctoria* (Indian indigo) or *Indigofera argenta* (silver indigo). *I. argenta* was favored because it had been cultivated in Egypt since the fourteenth century A.D. and grew wild in Nubia, Kordofan, Sennar, and Abyssinia. It is thought unlikely that the Egyptians obtained indigo from India (*I. tinctoria*) until a very late date. Lucas (29) points out that woad is the most likely source of Egyptian blue dye. According to him, woad was cultivated in the Fayum of Egypt in early Christian times and probably earlier. This would seem to give *Isatis tinctoria* priority over *Indigofera tinctoria*. The natural home of woad is not really known. It has been cultivated all across Western Asia, Southern Europe and England since early Christian and pre-Christian days and was used by the primitive Britons, according to Pliny and Ovid, to dye their bodies. *Isatis tinctoria* is only rarely cultivated today, having been almost replaced by indigo.

Isatis tinctoria is a handsome plant reaching a height of three to four feet and bearing rich yellow flowers. The dye is obtained from the leaves which are crushed and rolled into balls to dry. The balls are then powdered, wet again and allowed to ferment (the dye is not naturally present but is produced only by fermentation). After fermentation, the balls of woad are ready for use in dyeing.

Blue was usually used by the Egyptians on articles for the living, although at least one mummy wrapping exists which contains blue thread (2, 12, 27, 29, 36, 44, 45, 63).

Cucurbitaceae

Citrullus colocynthus. This is a climbing vine which bears a smooth, globular fruit about the size and color of an orange. The pulp of this fruit is soft and spongy and constitutes the colocynth ("bitter apple") of pharmacy. Colocynth is extremely bitter and poisonous, and is a drastic cathartic. It grows today throughout Western Asia and the Mediterranean region in general; also in several other parts of the world. In Palestine, Lebanon, Sinai, Egypt and Nubia, it grows wild in dry, sandy places and is very prolific. Apparently, it is native to this area of Western Asia and East Africa.

Pettigrew is, to my knowledge, the only writer to associate colocynth with embalming; he says it was an ingredient of one of the balsams used to prepare the dead. There is, however, mention (in an unknown connection) of colocynth oil (expressed from the seeds) in some papyri of the Graeco-Roman period (19, 27, 29, 35, 36, 38, 45).

Fagaceae

Quercus cerris. "Turkey oak" was proved definitely by the Kew Gardens to be the species from which the oak dowels in the shrines surrounding the sarcophagus of King Tut-ankh-amen were made. It grows today in the mountain forests in the Lebanon-Antilebanon region and may have been one of the oaks which, according to Theophrastus (58) and Pliny (43), grew in the vicinity of Thebes. Post (45) lists eleven species of oak growing in Syria, Palestine and Sinai and it is likely that the Egyptians also used species other than *Q. cerris* in various capacities (29, 42, 45).

Hamamelidaceae

Liquidambar orientalis. This tree is the Near Eastern source of the oleo-resin (and true balsam), storax (also called: styrax, liquid styrax, liquid storax, liquidambar). Chinese storax is obtained from *L. formosana* and American storax from *L. styraciflua.*

L. orientalis is native to Southwestern Asia Minor and it is rarely found outside that region today, although Tschirch and Stock (60) and Stuhlman (57) claim it may occur sporadically further east, i.e. around the Gulf of Alexandretta and Antioch. It is a medium-size tree, from 30-40 feet tall.

Storax is almost exclusively collected by a tribe of Turkish nomads called the Yuraks. They bruise the trunk of the tree and the balsam forms as a pathological reaction in the inner bark. The outer bark is scraped off and boiled in sea-water. The storax may then be skimmed off the top as it rises. For greater efficiency, the boiled bark is customarily pressed for still more yield of storax. The oleo-resin thus obtained is opaque, grayish and has a consistency approximating that of honey. It has a pungent, aromatic flavor and, on aging, acquires a pleasant balsamic odor. Storax has been used medicinally for many centuries, Pliny (43) having mentioned it in that capacity. It was used by the Egyptians, not only for embalming, but also in the preparation of ointments and perfumes. A piece of wood of *L. orientalis* was found in the eighteenth dynasty tomb of Tut-ankh-amen (19, 22, 27, 29, 30, 57, 60, 65).

Lauraceae

Cinnamomum cassia (Nees) Nees ex Blume and *Cinnamomum zeylanicum* Breyn. These are the sources of cassia and cinnamon respectively. The genus is native to Southeastern Asia and Malaysia. It does not exist in Africa or the Mediterranean area.

There is considerable doubt as to whether cinnamon and cassia were used in ancient Egypt and, if so, where they came from. The only evidence available of the use of cinnamon in dynastic Egypt (of an even slightly reliable nature) is the statement by Osburn quoted by Pettigrew (41) that on the surface of a twentieth dynasty mummy was ". . . a thick layer of spicery . . . (which) . . . still retains the faint smell of cinnamon or cassia." It may be noted that the odor of cinnamon is due to a constituent aldehyde, cinnamic aldehyde, and this is very susceptible to oxidation and volatilization so that it is, therefore, highly improbable that the odor could have persisted three thousand years.

There is, also, "evidence" in some of the ancient records. The oldest existing reference to cinnamon or cassia (they were frequently confused by ancient writers since they are very similar in many respects) is in the eighteenth dynasty Punt Reliefs wherein the loading of the vessels with, among other things, "cinnamon wood" is described. In the Karnak Reliefs of the nineteenth dynasty, it is written: "I gather together all the countries of Punt, all their tribute, of gum of myrrh, cinnamon . . ." And in the Papyrus Harris (twentieth dynasty) cinnamon is mentioned four times and cassia once in the lists of tributes.

It would thus appear that the ancient

Egyptians did have access to supplies of cinnamon and cassia. It is said that they were obtained in Punt which, in turn, must have received them from the Far East. But it is not so simple. There was no commerce between the Far East and Africa at so early a date. In 1500 B.C. (eighteenth dynasty), according to Laufer (25), Japan was not even in existence and China was yet a small inland agrarian community. China probably carried on no sea trade until about 200 B.C. Even though Laufer (25) proposes that Punt (or Egypt) received cinnamon and cassia from India or Ceylon instead of China or Indochina, there is still, according to W. S. Smith,* no real evidence of trade between Northeast Africa and the Far East until about the time of Alexander the Great in the third century B.C. There is considerable evidence that the two spices were to be had in Egypt, Greece, Palestine, etc., in the second and first centuries B.C., brought thence from India by the Phoenicians or Arabians. Strabo (56), writing in the first century B.C., mentioned India explicitly as a source of the spices.

It is very possible that the ancient records quoted above have been mistranslated; or, another alternative, as suggested by Fee (according to Laufer, 25) is that a fragrant bark, now extinct or unknown to us—perhaps a species of *Amyris*—once grew in Arabia or Ethiopia or both and it was to this that the ancient records refer.

It is extremely improbable, therefore, that the bark of *C. zeylanicum* or of *C. cassia* was ever employed by the ancient Egyptians in embalming or, indeed, that these two spices were even known to Egypt until the third or second century B.C., at which time Phoenician or Arabian traders, bringing the spices from India and/or Ceylon, introduced them to the entire Mediterranean area (6, 7, 8, 25, 29, 35, 39, 41, 49).

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*Personal communication.

Leguminosae

Acacia spp. . . Species of this genus are very numerous (about 420) and widely spread throughout the tropical and subtropical regions of the world; the majority are to be found about evenly divided between Australia and Africa, however. Post (45) lists eight species as indigenous to the Sinai-Syria-Palestine area and Muschler (36) mentions seven species growing in Egypt.

For many thousands of years *Acacia* spp. have supplied mankind with gum and timber. The timber is strong, elastic, naturally resistant to rot and fungal attack and although it is not easy to work, it was one of the earliest woods used by the Egyptians. According to the sixth dynasty Inscription of Uni: "His majesty sent me to Hatnub (middle Egypt) . . . (where) . . . I hewed for him a cargo-boat of acacia-wood." And later, "His majesty sent me to dig five canals in the South and to make three cargo-boats and four tow-boats of acacia wood of Wawat (in Nubia)." It would appear, then, that acacia timber was to be obtained in at least two places, both in the south, Middle Egypt and Nubia, which are known to have an indigenous growth of acacia.

Acacia is a small, thorny tree ranging in height from fifteen to thirty feet. but is sometimes stunted and shrubby. Its branches near the ground and the trunk may be as much as one foot in diameter. Not only is it an ancient source of timber, but it has also supplied the Egyptians with gum arabic (synonyms are based on the area of origin) since about the twelfth dynasty when it was reputedly used in making paints. Among other things, it also served to "stick" mummy wrappings.

Although many species of *Acacia* produce gum, today's main sources of gum arabic are *A. senegal* (L.) Willd. (*A. verek*), in the Anglo-Egyptian Sudan, and *A. arabica* (Lam.) Willd. var. *nilotica* (L.) Delile growing in Syria, Sinai, Egypt and south Ceylon, India, etc. . . .

The gum exudes naturally from the trunk of the tree, but this exudation is frequently abetted by breaking the bark without injuring the cambial layer or wood. The wound is at least two feet long. After three weeks to two months, there is sufficient exudation for gathering. The gum forms on the wound in large globular tears, soft at first, but gradually becoming hard. After picking, the tears are customarily bleached in the sun. Bleaching causes innumerable minute cracks to appear on the surface of the tear, giving it a characteristic opacity. Colors range from white through yellow and red depending on the source, species, method of preparation and many other factors. Gum arabic is used today in the textile, mucilage, paste, polish and confectionary industries and in medicine as an emulsifier and demulcent (5, 6, 18, 22, 29, 30, 32, 36, 45, 59).

Cassia acutifolia Del. Along with *Cassia angustifolia* Vahl., *Cassia acutifolia* is the source of true senna. *C. angustifolia* is native to Arabia and probably Africa and *C. acutifolia* is indigenous to the Anglo-Egyptian Sudan. Both species are straight, branched and about ten feet tall and both could have conceivably supplied the leaves from which senna, a cathartic of ancient usage, is derived.

However, its use as a cathartic dates only from the ninth century A.D. in Arabia and there is apparently no mention of senna in Egyptian records. The only suggestion that senna was used in embalming comes from Pettigrew (41), who claims that cassia and senna were components of "smyrea," a liquid used in the cheapest embalmings. We have seen the improbability that cassia was used and it appears likely that the same is true of senna. Pettigrew does not state his reason for believing that senna was a constituent of "smyrea" and it is extremely doubtful that it was used, in any capacity, in the embalming processes (30, 38, 41).

Dalbergia melanoxylon. "Ebony" may be the black heartwood of many kinds of tropical trees, but the "ebony" used in ancient Egypt (one might say the "true ebony" since the English word "ebony" is derived from the Egyptian "hebony") has been identified as *D. melanoxylon* (known today as African Blackwood). It is a small tree growing profusely in the scrub country and coastal regions of eastern Africa south of Egypt at least as far as Mozambique and Madagascar. African Blackwood is a dark, purple-plum color, very hard, close and free from pores. It is surprisingly easy to work and has long been a favorite material for the manufacture of clarinets, flutes, etc.

Ebony is mentioned often in Egyptian records as a material for the building of chests, shrines, coffins, etc., and although many articles of ebony have been found in tombs, there is yet to be discovered a coffin with even so much as dowels of ebony. Also, Egyptian records speak of ebony coming from Negro lands, Punt, Nubia, Genebteyew, Kush and the south countries, all of which are south of Egypt along the eastern coast of Africa. Apparently, the most ancient examples of ebony in Egypt are the small tablets and part of a cylinder seal from the first dynasty (1, 6, 21, 29, 57).

Linaceae

Linum is a large genus of herbs found in temperate and subtropical areas around the world. *L. usitatissimum* L., a cultigen, is the present-day source of flax. *L. angustifolium* Lodd., according to the majority of writers, is the parent of *L. usitatissimum* although there are others who claim that distinction for *L. perenne* L.

Flax has been under cultivation since prehistoric times, and there is naturally some doubt as to which species were (was) cultivated. Post (45) says *L. angustifolium* was cultivated prehistorically and that *L. usitatissimum* replaced it in more recent times; there is little quarrel with this conclusion. DeCandolle (12)

states that *L. usitatissimum* has been cultivated for at least four or five thousand years in Mesopotamia, Assyria and Egypt and that it was and still is wild between the Persian Gulf, the Caspian Sea, and the Black Sea. Indeed, it appears, according to Post (45), Vavilov (61), and others, that *L. usitatissimum* did originate in or around Mesopotamia. Vavilov also lists Central Asia and Abyssinia as centers of origin.

As for the origin of *L. angustifolium* itself, there can be even less certainty. It is found wild from the Canary Isles to Palestine and the Caucasus, and its seeds, capsules and the lower part of the plant have been identified in the remains of the Swiss Lake-dwellers' culture at Robenhausen.

The species cultivated by the Egyptians is likewise obscure. However, Unger (according to DeCandolle (12)) identified a capsule from a 13-14 century B.C. monument as resembling *L. usitatissimum* more than *L. angustifolium*. But there is really no reason to split hairs over this point. It is generally agreed that *L. usitatissimum* has been cultivated in Egypt at least since the beginning of the first dynasty and probably before. It is certainly conceivable that *L. angustifolium* was cultivated previous to the intrusion of *L. usitatissimum* and even that it persisted in cultivation, in at least some instances, for some time after the latter had gained dominance.

According to Ethel Lewis (26) the oldest existing fabric is of linen and this is certainly to be expected; the Egyptians have been weaving this textile for about six thousand years. They were the linen-makers *par excellance* of antiquity and produced cloth that ranged in quality from the very delicate to the very coarse. Egyptian techniques of linen-making are well described by T. Midgley (quoted by Lucas, 29). "The structure of textile fabrics of the earlier dynastic period in Egypt is now fairly well understood, and the character of the loom and its accessories equally well known. . . . From the tomb paintings . . . we have learnt how the flax stem was treated to obtain the bast fibers, how they were cleansed, heckled, roved, spun and warped. Finally, we have in these pictures the breast and warp beams shown pegged to the ground, lease rods and heddles inserted, and the weaving of cloth from carefully prepared yarns. No reed was used, so that . . . there is a great irregularity in the spacing of the warp threads as compared with modern fabrics; . . . Apart from this, it is singular how little within the range of plain weaving which is known today was not practised by the weavers of the Old Kingdom. . . . Thus at the very dawn of the historic period in Egypt we find the craft of the spinner and the weaver very highly developed in technique; manifestly the early stages of the evolution of the loom must be sought far back in the pre-dynastic era."

Linen manufacture was a large industry in Egypt and the Egyptians exported large quantities of it. The city of Apu was famous for its linen, and the city of Tanis was the center of linen manufacture in Lower Egypt. However, due to the large quantities exported, the industry must have flourished in other cities as well (7, 8, 12, 26, 29, 45, 61, 64).

Lythraceae

Lawsonia inermis (*Lawsonia alba*). This shrub is six to eight feet high and is widely distributed in the arid parts of north and east tropical Africa, Madagascar, tropical Asia and Australia. Most authorities believe that it originated in the East (Vavilov (6) says India) and spread early to the Mediterranean and Africa.

The leaves of *L. inermis* are dried, powdered and made into a paste called henna —a bright red, yellow or orange dye. The dye was and is used as a cosmetic and was probably used to stain the nails of mummies (although many writers feel that

stained nails could be due to the embalming materials) and, occasionally, to dye mummy wrappings.

The flowers are very fragrant and make an excellent perfume. It is likely that the Egyptians also employed the flowers in this capacity (8, 12, 27, 29, 30, 35, 36, 45, 61, 64).

Moraceae

Ficus sycomorus L. The "Egyptian fig tree" or "sycomore fig" is cultivated today in Egypt and may also be found along the eastern shore of the Mediterranean. That it grew in Palestine during Bible times, there can be little doubt; it is frequently referred to in the Bible (as "sycomore"). Strabo (56) says that it grew in Ethiopia and this would seem to be substantiated by several statements in ancient records which indicated that the sycomore fig was obtained in Punt (e.g. in the Papyrus Harris: "I planted incense and myrrh sycomores in thy great and august court in Ineb-Sebek, being those which my hands brought from the Country of God's-Land"). Theophrastus (58) states that the "sycomore fig" grows in Egypt and Lucas (29) seems to feel that the Egyptians had a domestic supply of the tree. Schweinfurth, according to Muschler (36), places the origin of *F. sycomorus* in Yemen just east across the Bab-el Madab straits from Punt.

F. sycomorus is an evergreen, growing to a height of 30-40 feet and sometimes attaining a trunk girth of 20 feet. The wood is very soft and porous, but is, nonetheless, very durable and was a great favorite with coffin-makers. Sycomore fig coffins have been discovered which date from the twelfth dynasty and up through the twenty-sixth dynasty. Remains of *F. sycomorus* have been found in predynastic graves (6, 29, 35, 36, 45).

Rhamnaceae

Zizyphus spp. This genus embodies about fifty species scattered about the tropics and subtropics of the world but found chiefly in Asia and America. The wood, sidder, found in a third dynasty plywood coffin and later as coffin dowels, was probably (according to Lucas (29)) obtained from *Z. mucronata* Wilbl. or *Z. spina-Chrisi* Lam., but the sidders are exceptionally difficult to differentiate even by microscopic examination. *Z. mucronata* is quite common in the drier parts of tropical and southern Africa and the Sudan and might have been used by the Egyptians except, according to Lucas (29), that there is no mention in ancient records of woods other than ebony and certain sweet and fragrant types having been brought from the south of Egypt. *Z spina-Christi* is probably the species used in coffin construction. It grows throughout the Mediterranean region including Egypt, the Levant and tropical Africa. It is a small tree, 9-15 feet tall, and thus too small to be extensively used in coffin construction, but it apparently grew in Egypt, was hard and durable and large enough for dowels.

The dried fruit of *Z. spina-Christi* has been found in predynastic remains. It may have been this part of the plant that was used in kyphi ointment (29, 30, 35, 36, 45).

Tamaricaceae

Tamarix spp. This genus contains about seventy species. They are numerous in temperate Asia and around the Mediterranean; Muschler (36) lists eight species growing in Egypt and Post (45) twelve in the Lebanon-Palestine-Sinai region. *Tamarix* (or tamarisk) is definitely indigenous to Egypt, stems and branches from the late Quartenary Period having been found in the Wadi Qena (29).

Tamarisk is a halophyte and may be found growing profusely in the salty deserts and along the sea coasts. The tree is usually straight and may range in height from a few to one hundred feet, but in the desert it is frequently a gnarled shrub. The wood is hard, tight, heavy and workable and was used for walking sticks, etc., as early as the Middle Kingdom. It did

not find its way into coffin construction until about the twentieth dynasty.

Tamarisk is mentioned ("tamarisk bundles") in the twentieth dynasty Papyrus Harris and Pliny (43) states that ". . . in Syria and Egypt this shrub is abundant." It is now generally supposed that the "manna" eaten by the Israelites during their trek from Egypt was the hardened, sweet sap of *Tamarix* spp. drawn off, predigested and exuded by aphids (4, 6, 9, 28, 29, 35, 36, 45, 53, 64).

Vitaceae

Vitis vinifera. The records of the cultivation of the grape and of the making of wine in Egypt go back five or six thousand years. Wide cultivation of the grape since ancient times complicates the problem of origin, but Vavilov (61) places it in the Near-Eastern center (interior of Asia Minor to Turkmenistan), DeCandolle (12) places it to the south of the Caucasus and Post (45) says ". . . its home is between the southern shores of the Caspian Sea and the Taurus."

V. vinifera grows today in Egypt, Lebanon and Palestine (and elsewhere) and *V. orientalis* may be found in Lebanon and Palestine. Although there can be no real certainty as to the species employed by the Egyptians in wine-making and as raisins which were used in kyphi ointment, it is generally conceded that it was *V. vinifera* (8, 12, 35, 36, 45, 61).

TABLE I
SUMMARY OF PLANTS MENTIONED IN THIS PAPER

NAME	PAGE	PART OR PRODUCT USED	USE
Abies cilicia Carr.	89	Exudate, wood	Embalming, coffins
Acacia spp.	98	Exudate, wood	Coffins, paints, adhesive
Allium cepa L.	92	Bulb	Religious, embalming (?)
Aloe succotrina Lam.	92	Exudate, fiber	Embalming (?), wrappings (?)
Boswellia spp.	93	Exudate	Embalming
Carthamus tinctoria L.	95	Floret	Dye
Cassia spp.	99	Leaf	Embalming (?)
Cedrus libani Loud.	89	Wood	Embalming, coffins
Cinnamomum spp.	97	Bark	Embalming (?)
Citrullus colocynthus (L.) Schrad.	96	Fruit	Embalming (?)
Commiphora spp.	95	Exudate	Embalming (?)
Crocus sativus L.	92	Stigma	Dye (?)
Cupressus sempervirens L.	89	Wood	Coffins
Cyperus papyrus L.	90	Pith of stem	Embalming
Dalbergia melanoxylon Guill. & Perr.	99	Wood	Coffins (?)
Evernia furfuracea (L.) Ach.	88	Whole plant	Embalming
Ficus sycomorus L.	101	Wood	Coffins
Isatis tinctoria L.	96	Leaf	Dye
Juniperus spp.	89	Wood, fruit	Coffins, embalming (?)
Lawsonia inermis L.	100	Leaf	Dye
Linum spp.	99	Fiber	Wrappings, embalming
Liquidambar orientalis Mill.	97	Exudate	Embalming
Phoenix dactylifera L.	93	Exudate	Embalming
Pinus halepensis Mill.	90	Exudate	Embalming
Pinus pinea L.	90	Exudate	Embalming
Pistacia lentiscus L.	93	Exudate	Embalming
Quercus cerris L.	97	Wood	Coffins
Tamarix spp.	101	Wood	Coffins
Taxus baccata L.	90	Wood	Coffins
Vitis vinifera L.	102	Fruit	Embalming
Zizyphus spp.	101	Wood, fruit (?)	Embalming (?), coffins

Appendix

CHRONOLOGY OF ANCIENT EGYPT
(after W. S. Smith. Ancient Egypt as Represented in the Museum of Fine Arts, 3rd ed., 1952)

Prehistoric:
- Pre-dynastic: 4000-3200 B.C.

Archaic Period: 3200-2680 B.C.
- Dynasty I: 3200-2980 B.C.
- Dynasty II: 2980-2780 B.C.
- Dynasty III: 2780-2680 B.C.

Old Kingdom. 2680-2258 B.C.
- Dynasty IV: 2780-2680 B.C.
- Dynasty V: 2565-2420 B.C.
- Dynasty VI: 2420-2258 B.C.

First Intermediate Period: 2258-2052 B.C.
- Dynasty VII: Interregnum
- Dynasty VIII: 2258-2232 B.C.
- Dynasty IX: 2232-2180 B.C.
- Dynasty X: 2180-2052 B.C.

Middle Kingdom: 2052-1786 B.C.
- Dynasty XI: 2052-1991 B.C.
- Dynasty XII: 1991-1786 B.C.

Second Intermediate Period: 1786-1570 B.C.
- Dynasties XIII-XIV: 1786-1680 B.C.
- Dynasties XV-XVI: 1720-1570 B.C.
- Dynasty XVII: 1600-1570 B.C.

New Kingdom: 1570-1085 B.C.
- Dynasty XVIII: 1570-1349 B.C.
- Dynasty XIX: 1349-1197 B.C.
- Dynasty XX: 1197-1085 B.C.

Period of Decline: 1085-663 B.C.
- Dynasty: XXI: 1085-950 B.C.
- Dynasty XXII: 950-730 B.C.
- Dynasty XXIII: 817 (?)-730 B.C.
- Dynasty XXIV: 730-715 B.C.
- Dynasty XXV: 751-663 B.C.

Saite Period: 663-525 B.C.
- Dynasty XXVI: 663-525 B.C.

Foreign Domination

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The reader is referred to the many excellent works on Ancient Egyptian flora by Schweinfurth, by Keimer and by Tackholm.

BOOK REVIEWS

A Glossary of Pigments, Varnish, and Lacquer Constituents. J. H. Martin and W. M. Morgans. 111 pp. Chemical Publishing Co. N. Y. $3.50.

This small volume contains precisely what the title implies. It is a glossary of the compounds and a few technical terms used in the formulation of paints. The individual entries are not sufficiently detailed for the industrial chemist and are too vague for the novice. The materials include a number of plant products which are very briefly described. It is difficult to determine the value of this book for anyone other than a specialist from another field who desires a dictionary of currently used terminology in the paint industry.

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The Pharmacology of Plant Phenolics. J. M. Fairbairn, Editor. Academic Press, Inc., New York 3, New York, 1959. viii + 151 pp., 33 figs., 20 tbls. $6.00.

This volume is an outgrowth of a two day plant phenolic symposium held at the University of Oxford, England, in April, 1958. The symposium was held under the auspices of the Plant Phenolics Group, a professional society of biologists and chemists interested in the practical and research aspects of plant phenols and related derivatives.

The contributors, the majority English, presented eleven papers on non-nitrogenous plant phenolics. Approximately one-half of the allotted symposium time was devoted to the physiologic and pharmacologic significance of the bioflavanoids. The remaining eight papers included: the pharmacodynamics of serotonin and nor-epinephrine, the *in vivo* fate of phenolics, the toxicity of simple and complex phenols, the anthraquinones, estrogenic phenolics, the antimicrobial activity of grape and wine phenol derivatives, and the nature and extent of phenolic compounds in plants ingested by man as foodstuffs.

Fairbairn's paper is especially noteworthy. Evidence is presented that the anthraquinone vegetable cathartics are specifically active, not as the free anthraquinones (as is erroneously stated in pharmacology texts) but as the anthrone glycosides, the carbohydrate moiety conferring metabolic transport and protective qualities to the anthraquinone molecule.

The paper presented by Dr. J. H. Burns, on the pharmacology of serotonin and catecholamines of animal origin, unfortunately fails to mention the known occurrence of these compounds in the pulp and peel of the common banana. In addition, this same paper propagates the exaggerated claims for serotonin as a normal physiologic vasoconstrictor substance.

Pertinent roundtable discussions follow the majority of the presentations and add materially to this book's scope and depth of subject matter coverage. A short glossary of elementary scientific terms is appended. This work is clearly written in large, readable type and is, in general, carefully edited. A notable shortcoming of the text, however, is the lack of a necessary subject index, an essential factor if the book is to be gainfully employed as a reference work.

This text adds significantly to the knowledge of the widely distributed non-nitrogenous plant phenolics. It should prove a valuable addition to the personal library of the phytochemist, botanist, pharmacognocist, and find a ready home on the bookshelves of all pharmacy school libraries.

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Some Tropical South Pacific Island Foods: description, history, use, composition, and nutritive value. Mary Murai, Florence Pen, and Carey D. Miller. xii + 159 pp., 32 illus., 14 tables, bibliog., index. University of Hawaii, Honolulu, 1958. $2.00.

In non-western areas where it has been asserted that the health and general vitality of the local population are more adequately maintained by the effective use of traditional foods than by the introduction of so-called "civilized" fare, detailed analyses of native foods and associated dietary behavior are of considerable importance. The authors of this handsome volume on certain Micronesian and Polynesian foods recognize (p. 2) that such claims have been made repeatedly for parts of Oceania. In this book they have provided some of the data needed for the objective evaluation of these claims.

Most of this report is based on the laboratory analysis of native plant foods collected by the senior author in the summer of 1951 on the Micronesian islands of Majuro Atoll (in the Marshalls) and Truk (in the Carolines). Of the 67 plant food samples assayed for nutritive value, only 11 came from other islands (Samoa 5, Hawaii 2, Kapingomarangi 2, Gilberts 2). The results of the technical analyses are presented in concise descriptive paragraphs accompanied by tables summarizing the quantitative data under standard rubrics. In general, the photographic illustrations are excellent. Details of collection, preservation, and laboratory techniques used are systematically accounted for in the Appendix (pp. 105-136). There is a brief supplement (11 pp.) on a few Micronesian sea foods analyzed by Drs. Hiroyuki Iwao and Kunitaro Arimoto of Tokyo.

Despite its many useful features, the overall organization of this report and, in particular, its historical, comparative, and non-nutritional descriptive statements about plant foods and native diets, leave much to be desired. In the interests of those who are seriously concerned with continuing research on Pacific foods, I would like to make this criticism more explicit.

First, the book lacks a general introduction defining its content, scope, and purpose. The specific geographic setting is neither delimited nor discussed in terms of its representativeness in the broader Oceanean perspective. The breadth of the title and the scale of the single map (on which neither Majuro nor Truk are identified or identifiable) only add to the general impression of imprecision. The reasons for including some foods and excluding many others equally important in "some South Pacific" islands receive little attention. That even an approximate balance has not been achieved can be seen by tabulating the types and numbers of sample foods discussed (in sequence and labelling I follow the authors):

Breadfruit		25
Coconut		19
Pandanus		6
Other Fruits	(banana)	3
	(apuch)	1
Starchy Aroids	(taro)	4
	(*Cytosperma*)	6
	(*Alocasia*)	1
Other Starchy Roots:	Arrowroot flour	1
	Sweet potato	1

Yams are not even mentioned.

Secondly, while some attempt at providing comparative and historical data is implied, the selection of sources is unfortunately very spotty. Neither in the text nor in the bibliography of 70-odd titles does the reader find references to such standard works on tropical Pacific island plant foods as W. H. Brown's *Useful Plants of the Philippines* (3 vols., 1941-3, Manila), and I. H. Burkill's *A Dictionary of Economic Products of the Malay Peninsula* (2 vols., 1935, London). Recent publications reporting significant nutritional work on many of the same plant foods in other parts of the Pacific also remain unmentioned and apparently unconsulted (e.g., see C. Ll. Intengan, *et al.*, "Composition of Philippine Foods, I-V," *Philippine Journal of Science*, 1953-1956, Manila).

Thirdly, the ethnographic and specifically dietary data are fragmentary at best and in many cases appear to consist of unorganized, raw field notes. Native names, written in an unexplained orthography, and not always

identified by language, do not necessarily make this unsystematic presentation of the contextual data any less disappointing.

In sum, the chief value of this book lies in the detailed nutritional data it provides for a miscellaneous assemblage of plant foods from two regions in Micronesia. In future attempts of this sort, it is hoped that field and later analytic research will include correspondingly systematic observations of contextual factors which must be known if significant dietary and cultural interpretations are to be expected after the laboratory assays have been made. If one is already familiar with food problems in the Pacific tropies, he may consult the nutritional sections of this report with profit; for an organized introduction to such problems he will have to look elsewhere.

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Dictionary of Economic Plants. J. C. Th. Uphof. H. R. Engelmann (J. Cramer), Würzburg. (Hafner Publ. Co., N. Y.) 400 pp. 1959. $9.75.

This dictionary will be useful to librarians, scientists, industrialists, and laymen. It offers a quick reference for those casually interested in particular pieces of information on useful plants. That over 6,000 species names of plants have been considered is one indication of the extent of coverage. Many common names are included, and these are referred to the Latin equivalent. Under the Latin name, the botanical family is given, the habit of the plant (herb, shrub, tree, etc.), broad geographical distribution, uses, and other short items of information. The major chemical constituent may be mentioned, if this is important.

A bibliography, subdivided by broad categories of uses and by geographic regions, is provided. Although most of the outstanding reference works are listed, the list is by no means exhaustive.

Such an extensive endeavor as this, undertaken by one author, inevitably contains something with which a specialist could disagree. The botanist interested in nomenclature will find inconsistencies in the appropriate family names, in synonymy, in spelling. An editor would note that the book, though written in English, must have had a German proof reader, etc., etc. Some of the names included as separate entities are actually synonyms of others. As an example, *Manihot dulcis* is not botanically distinct from *M. esculenta.* It is certainly not within the realm of possibility for Dr. Uphof to have personal knowledge of all such problems. He must rely on printed works which are not only scanty but, in many cases, quite incomplete.

These points detract from the total value of Dr. Uphof's dictionary to some extent. One value which the Dictionary of Economic Plants may have is to emphasize the great need for an exhaustive literature search for that which is known of plants used by man. The book is quite useful, either as the first source of information when more is needed, or to serve as "fill-in" information to a questioning layman.

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Plant Breeding and Cytogenetics. F. C. Elliott. 395 pp. McGraw-Hill Book Company, Inc. New York. 1958. $8.50.

In this textbook the author has undertaken an approach to the subject emphasizing the "biological principles underlying plant breeding", which encompasses an area of impressive breadth. The first six chapters are devoted primarily to a consideration of reproductive and chromosomal mechanisms in relation to variability, and to the use of cytogenetic technique in such breeding procedures as interspecific gene transfer. Much of the material on the application of induced mutations, polyploidy, and chromosomal substitutions in plant breeding is accorded textbook treatment for the first time. Certain aspects, such as the genetic consequences of polyploidy, and recombination and selection in relation to quantitative characters, might profitably have been examined at greater length. Although rather abbreviated in a number of these areas and somewhat less than encyclopedic in scope, the treatment of the material in the first half of the book is well intergrated and should prove stimulating to students of plant breeding and to others interested in this field.

The second segment of the text consists of four chapters dealing with the manipulation of variability in the improvement of crop plants. This material is treated primarily in an applied plant breeding frame of reference. The author states (p. 224) that biometrical approaches to studies of quantitative inheritance lie beyond the scope of the text, which is probably reasonable at the present time. However, his statement that the models devised in population genetics are useful in the theoretical study of quantitative gene action but have little direct value because the results cannot be interpreted in simple practical terms undoubtedly will be challenged. Among information inconsistent with this thesis might be cited that obtained by the statistical genetics group at North Carolina in studies on grain yield in corn. The author's decision to minimize quantitative considerations posed certain limitations in dealing with the material in this second part of the book. Aside from this, some segments of the material would have benefited from an amplified treatment, a notable example being heterosis. The final three chapters in the text are concerned with varietal testing, the handling of materials after varieties are released, and the organization of plant improvement work in various countries.

A number ot errors have found their way into the text. Most of these are relatively minor, such as the statement in the caption to fig. 1-13 that the silks from the upper part of a corn ear are the first to emerge, or the mating of two male sterile parents in the first line of fig. 1-20. A few, such as the reasoning given for the percentage of n-1 megaspores produced by a monosomic wheat plant (p. 181) are more serious. The author anticipates in his preface that the text will be of greatest use and interest to advanced students. The terse discussions of many topics, however, undoubtedly will be a source of difficulty to readers not readily familiar with such diverse phenomena as apomixis, controlling elements, cryptic structural differentiation of the chromosomes, and over-dominance. The fact that the reader must refer to Stebbins (1947) to find out what segmental allopolyploids are, to Ford (1955) to learn of the important evolutionary consequences which accrue from changes in population size of a species, and to other workers for specific information on a variety of other subjects is likely to detract from the value of this work as a textbook.

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